Nijmegen Institute
for Cognition
and Information

DYSLEXPERT

The development and evaluation of an expert system for the diagnosis of reading and spelling problems

Anita Blonk

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The development and evaluation of an expert system for the diagnosis of reading and spelling problems

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van de Sociale Wetenschappen

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The research reported in this thesis was carried out under the auspices of the Diagnostic Unit at the Nijmegen Institute for Cognition and Information. The research program consists of a cluster of descriptive, prescriptive, and evaluative studies of the diagnostic process. In one of these clusters, to which this thesis belongs, the diagnostic process in the field of beginning reading and spelling was studied. In this thesis, the diagnostic decision-making in the field of beginning reading and spelling of one particular expert was described in the form of an expert system. An expert system is "a program that relies on a body of knowledge to perform a somewhat difficult task usually performed only by a human expert" (Parsaye & Chignell, 1988; see also Chapter 1, page 9). The general goal of the project was to gain greater insight into the intricacies of expert knowledge and the way the expert applies such knowledge in his daily routine. The creation of the expert system and its evaluation were tools rather than goals. This does not mean, however, that our work does not have practical value as will be shown in the evaluative section of this thesis. Expert knowledge can be applied in different ways and, as the use of textbooks shows, does not depend on the availability of an expert system. However, if the process of explicating and formalising is successful, it is nevertheless wise to implement this knowledge into an expert system for consultation by practitioners.

We believe that an expert system can significantly contribute to diagnostic practice by providing a 'second opinion' and also by making the specific knowledge and problems involved in this reasoning process more transparent. In addition, a standardisation of the diagnostic process can be facilitated and this, in turn, will enhance the reliability of the diagnostic decision-making process. Greater agreement among diagnosticians can be insured by reducing the differences in theoretical orientation, procedural differences and differences, in the degree of accumulated experience.

In an expert system, the theoretical foundations are made explicit and accessible. In this project, a system is developed in which the knowledge of a particular expert is stored. A diagnostician who uses the system is free to agree or disagree with the theoretical foundations depending on the school of thought he is working from.

An expert system also incorporates standard procedures as well as standard assessment instruments. Diagnosticians are therefore obliged to follow a similar course to diagnosis and treatment. This should lead to greater agreement. Finally,

by viewing the expert system as 'the standard case' based on extensive past experience, diagnosticians are in a position to compare the features of a new case to this 'golden' standard. Once again, greater diagnostic consistency should be the result.

Expert knowledge is, by definition, highly private knowledge. This knowledge is not only private but also specific in the sense that one expert does not have to agree with another one in the same domain. The researcher is therefore always left with the problem of selecting an expert. This selection-issue is of paramount importance when one tries to extract implicit knowledge. The explication and formalisation of implicit knowledge is a cumbersome task that requires painstaking attention. So one always has to start with just one expert. In this project, the expert in question was one of the few top experts on the subject in The Netherlands. His publications on the subject are standard literature at universities and colleges. His ideas with regard to the diagnosis and treatment of dyslexia are the foundation for a professional school. In Nijmegen, he worked with and supervised a group of diagnosticians and therapists who were trained by him. Moreover, he had extraordinary practical experience, and, at the start of the project, was still busy as a practitioner.

The illness and death of this expert during the project was a tremendous loss, not only for the field but for this project in particular. It was no longer possible to pursue the original validation of the structured knowledge by asking the expert to decide about cases. However, a useful evaluation is developed by asking a group of experienced diagnosticians who had been working closely with the expert, to co-operate.

A final few comments on some of the decisions made during the development of the expert system are now warranted. It should be noted that the participation of an expert means a commitment to the diagnostic approach and theoretical framework preferred by this person. Our expert clearly favoured an information-processing approach to the process of reading and spelling. The knowledge base for the expert system developed here will therefore represent mainly this approach. Many of the theoretical considerations involved in the development of such a system and even the notion of dyslexia, itself, may also, therefore, be open to debate. Given the goal of obtaining greater and better knowledge of the diagnostic decision-making process, however, such a bias should not be a problem. That is, the quality of the expert, the validity of the knowledge base, and the neutrality of the expert system are not of central importance. Dependence on the particular diagnostic approach and theoretical framework advocated by an

expert is, rather, inherent to the use of expert knowledge. Put differently: If the expert did not endorse a particular diagnostic approach and specific theoretical framework, then he might not be considered an expert!

In Chapter 1, the background of the present project will be discussed: the domain of diagnosing reading and spelling problems, the psychodiagnostic process and its difficulties, and some formal solutions to these difficulties. The typical kinds of knowledge necessary for the diagnostic process will therefore be explored and just how an expert problem solver conducts the diagnostic process will be examined.

In Chapter 2, the results of the process of knowledge analysis will be described. The methods for analysing and structuring the expert knowledge will be outlined along with the various levels of knowledge structures established.

In Chapter 3, the expert system DYSLEXPERT, its knowledge base, and its procedures will be described.

In Chapter 4, the results of an empirical study concerned with the evaluation of DYSLEXPERT and comparison to human diagnosticians are reported. A number of conclusions and problems are then discussed. This chapter is published in the journal *Computers in Human Behavior* (Vol. 12 (4), pp. 567-586).

In Chapter 5, an overview of the knowledge-engineering process and the empirical research reported in this thesis is provided. The insights gained during the development and evaluation of DYSLEXPERT will be reported along with recommendations for further evaluation and development.

Chapter 1
The practice of diagnosing reading and spelling problems and the role of knowledge-based systems

This first chapter contains a variety of topics and is intended to provide background information for the research described in this thesis. In this chapter the daily practice of diagnosing reading and spelling problems and the potential contributions of knowledge-based systems (KBS) are considered. In section 1.1, the domain of reading and spelling problems is briefly described. In section 1.2, procedures and knowledge structures commonly employed by diagnosticians are reviewed along with a number of the problems associated with the diagnostic process. In section 1.3, it is argued that a formal approach constitutes an important tool for the solution of some of the problems confronted in diagnostic practice, and that a knowledge-based approach is particularly suited to this task.

1.1 Reading, spelling, and dyslexia

1.1.1 Reading and spelling

Reading and spelling are central to everyday functioning and important determinants of a successful school career. Reading and spelling represent two different cognitive processes but are closely linked. Reading involves the identification of graphemic features in order to grasp the meaning of a word while spelling involves the production of the graphemic features for a particular word. The domains of both reading and spelling are the object of the expert system developed here.

The reading process consists of several subprocesses including the perception of hand-written or printed letters, the understanding of words, the understanding of the structure and meaning of a sentence, and the understanding of connected sentences in text (Noordman, Eling, & Thomassen, 1991). In the literature, various reading models are described: bottom-up models (e.g., Gough, 1972), top-down models (e.g., Goodman, 1970) and interactive models (e.g., Rumelhart & McClelland, 1981). In these models, the components of the reading process and the sequence in which the components are executed, are described. In all of the models, the mental lexicon is a central component where all information concerning a word is stored: pronunciation (the phonological representation), spelling (graphic representation), meaning, and grammatical function.

Ellis (1984) has developed a model of the spelling process in which two routes are distinguished: addressed and assembled spelling. In the first route, addressed spelling, the meaning of a word leads to the graphemic code in the mental lexicon and thereby allows the word to be written down. In the second route, assembled spelling, the phonemic code is first identified and then translated into a graphemic code using phoneme-grapheme correspondences.

The development of reading and spelling skills clearly depends on school practices. Reading is mostly taught using a bottom-up approach. Grimbergen (1994) developed a computer program for simulating the reading of isolated words. It incorporates three commonly proposed routes for the identification of words. In route A, already skilled readers use the graphemic entry in the mental lexicon to extract the meaning of a word. In route B, a letter-grapheme-phoneme translation has to be executed in order to extract the meaning of a word. In route C, a letter-grapheme-phonic-phoneme transition has to be executed. Route A is fast but not directly available to beginning readers, who usually start with routes B and C. Reading whole sentences or text involves still other models: top-down and interactive reading. To read sentences, automation of word reading (route A) is needed to free working memory for comprehension of the text in general.

Van Bon (1993) describes three phases in learning to spell. In the first stage, the speller uses phoneme-grapheme correspondence rules to write each speech unit sequentially. In the second stage, the speller must learn the conditions for specific spelling. In the third stage, the speller learns specific rules for groups of words and learns by analogy (that is, compares the spelling of a new word to the spelling of already familiar words).

1.1.2 Dyslexia, reading and spelling problems

Between 7% and 10% of all school-aged children manifest reading and spelling problems (Van Dongen, 1984; Dumont, 1984). The problems often persist into adolescence and adulthood (and particularly in connection with the learning of a second language). In 2% to 3% of all the cases, the children do not have other learning problems; the parents also do not suspect a reading problem as the child has performed normally in all other learning activities. This group of children has a *specific reading disability*, also called *dyslexia*. In contrast, children with other learning deficits as well as reading problems are commonly referred to as *weak readers* or *children with reading problems* (Yule & Rutter, 1976). Often, people who are dyslexic also have spelling problems, and by analogy to the word *dyslexia*, are often referred to as having *dysorthography*.

Dyslexia is often defined according to Critchley (1970):

" [Dyslexia is] a disorder manifested by difficulty in learning to read despite conventional instruction, adequate intelligence, and sociocultural opportunity. It is dependent upon fundamental cognitive disabilities which are frequently of constitutional origin" (p. 11).

Dumont (1990) identifies dyslexia on the basis of the following criteria: only reading problems, no other significant handicaps, at least normal intelligence, reading problems can be attributed to language deficiencies, discrepancy exists between expected scholastic achievement and ongoing performance, visual and auditory capacities have developed unequally, and some indication of genetic transmission can be found.

In both the definition offered by Critchley and the criteria provided by Dumont, a specific reading problem is largely determined through exclusion of all the other kinds of problems. Nevertheless, both authors label a reading problem as dyslexia provided it has a constitutional origin, and Dumont (following Vellutino, 1979) requires some language deficiencies.

The exclusionary approach has some problems. As Van Aarle (1991) points out, constitutional origins can also exist in children with other problems such as a disturbed family interaction or a poor education. Dyslexia may also be a diagnosis reserved only for those children who do not happen to have an intellectual, social, or cultural problem in addition to a reading problem – which is clearly open to question.

In addition, the requirement of at least normal intelligence is disputable. At least normal intelligence excludes individuals with below-normal intelligence and a level of reading achievement that is far below this level; according to the common definition, these people do not have dyslexia. Similarly, individuals with a high level of intelligence and only normal reading achievement are not considered dyslexic while this is clearly possible. In other words, intelligence substantially correlates with reading level and a discrepancy between the two may at times be indicative of a specific reading disability.

A final important problem with the exclusionary approach is the overly rigid distinction between external and internal causes. In practice, it is virtually impossible to separate the contributions of external and internal factors (such as a constitutional predisposition) to a reading problem. More often than not, the reading problem can be attributed to the interaction between an internal cause and diverse external circumstances. Just and Carpenter (1987) also observe that this

"... approach produces a more homogenous sample of dyslexics, but it may be an atypical sample [of the population]" (p. 364).

A more open definition is provided by the inclusionary approach, where someone is simply defined as dyslectic if he or she has severe reading problems. Other problems, such as low level of intelligence, emotional problems, poor schooling, and so on are not excluded. The inclusionary approach leads to a model with multiple causes and a taxonomy of types for dyslexia (e.g., Bakker, 1986; Boder, 1973; Johnson & Myklebust, 1967).

Just and Carpenter (1987) suggest that the inclusionary and exclusionary approaches each have their own purpose:

> "The inclusionary approach is useful for evaluating the influence of non reading factors on dyslexia, for estimating the incidence of severe reading problems, and for formulating public policy, such as deciding who should receive remedial education. The exclusionary approach is useful for isolating dyslexia in a form that may be more amenable to cognitive research. After an adequate model has been formulated and the basic processes in dyslexia are understood, the exclusionary approach could be broadened to investigate how the other factors affect the basic processes." (p. 366)

In the present thesis, we adopt the exclusionary approach to the diagnosis of dyslexia. Our expert is a proponent of the exclusionary view, and we therefore chose to model the domain of knowledge associated with this view of dyslexia.

With regard to the exact nature of the dyslexic disturbance itself, there is also little agreement. Noordman et al. (1991) prefer a description of the normal reading process and the problems that can occur during this process. In such a way, the potential differences between dyslexics and other reading-disabled individuals may be obliterated. State-of-the-art research, however, does not allow further distinction.

A variety of the subprocesses involved in reading can go wrong: visual encoding, word recognition, and the comprehension of words, sentences, and text. Persistent problems may occur in the automatisation of word-reading and the phonological decoding of visual information. When the direct and indirect entries in the mental lexicon are not as quickly accessed as in skilled readers, errors and slow reading may be observed. The fact that the reading process in dyslexics and other reading-disabled individuals is distorted by verbal coding deficits such as phonemic segmentation and slow verbal retrieval is generally accepted (Dumont, 1990; Just & Carpenter, 1987; Rayner & Pollatsek, 1989; Van Aarle, 1991). Vellutino (1979) settled the question on whether dyslexia has a visual or auditory cause in favour of the auditory position. Nevertheless, recent research shows that faulty eye movements and perceptual disorders also interfere with the reading process (Rayner & Pollatsek, 1989). Neurological research shows correlates between dyslexia and minor cerebral distortions, particularly in the language areas but also in the cells associated with the visual system (Galaburda, Rosen, & Sher-

man, 1989; Hynd & Semrud-Clikeman, 1989). Once again, however, the distortions do not appear to be specific to dyslexia.

The various subprocesses involved in spelling – ranging from the phoneme-grapheme translations to learning by analogy – may also be disturbed. Moreover, the spelling problems may be located in the visual system, the auditory system, the phoneme-grapheme translation system, the language system, or the knowledge of specific spelling rules. For a more complete overview of the problems and conditions associated with reading and spelling disturbances see Dumont (1990) and Van Bon (1993).

1.2 Diagnostic practice and formal modelling

1.2.1 The diagnosis of reading and spelling problems

The initial diagnosis of reading and spelling problems often comes from the teacher in the classroom. From informal observation the teacher is already aware of how the child's reading speed, reading fluency and error patterns differ from other children with the same amount of teaching. A more systematic approach like, for example, the task-analytic approach for the diagnosis of reading problems (Struiksma, Van der Leij, & Vieijra, 1986), can provide additional information with regard to the child's reading difficulties. Spelling problems are also often examined by classifying the errors. In some cases, a teacher will request the opinion of an educational psychologist. The question is usually: 'What causes the reading or spelling problems?'

The activities involved in the diagnosis of reading and spelling problems largely consist of obtaining and integrating information from a variety of sources (parents, teacher, child, tests, observations, schoolwork), and reporting the diagnosis and treatment to the clients. A procedure often used in practice consists of three general phases: an intake examination (anamnesis), psychodiagnostic assessment, and the provision of a diagnosis with treatment recommendations. This procedure usually requires between 10 to 14 hours of work with most of the time being devoted to the administration of tests. During the intake examination, the diagnostician obtains information from the parents and school reports. During this phase, the diagnostician usually develops some preliminary hypotheses about the nature of the problem(s). In the second phase, the clinician uses (mostly standardised) tests to obtain more information about potentially-relevant matters such as intelligence, language development, personality, and reading/spelling performance. In the third phase, all of the information with regard to a particular

case is interpreted. An extensive case description is constructed, conclusions are drawn concerning the cause of the dysfunction, possible treatments are considered, and a final recommendation for the parents (or client) is made. In Appendix A, an extensive sample of a report to the parents of a child with reading problems can be found.

1.2.2 Diagnostic decision-making: Reasoning and knowledge structures

In diagnostic decision-making, a diagnostician has to reason with knowledge that is always represented in a more or less explicit structure.

Influential research in the area of medical decision-making has been performed by Elstein, Shulman, and Sprafka (1978). In a ten-year retrospective, Elstein, Shulman, and Sprafka (1990) summarise their original findings and compare these with the findings of subsequent research. In the diagnosis of medical problems, they distinguish between hypothetico-deductive reasoning and pattern-recognition or direct automatic retrieval. Hypothesis generation is seen as a 'psychological necessity' to cope with the complex clinical situation, the potentially massive amount of data, and the limited capacity of the working memory. The thoroughness of the data collection and the accuracy of the diagnosis do not appear to be correlated. The number of hypotheses either generated or considered at one time also does not appear to correlate with the accuracy of the diagnosis, however. Successful diagnosis, rather, appears to be case-specific: a diagnostician may easily solve one case, but fail to solve the other.

As suggested by Groen and Patel (1985), expert diagnosticians may use another form of reasoning, namely pattern-recognition or direct automated retrieval. In such an approach a small set of if-then production rules is used to go from the data to the diagnosis without the generation of actual hypotheses. This process is often called 'forward reasoning' and contrasted to hypothetico-deductive or 'backward reasoning'.

Kleinmuntz (1990) suggests that practitioners receive little feedback with regard to their diagnoses and are therefore not in a position to learn from experience, or clearly organise their knowledge. He states that a well-structured knowledge clearly facilitates the invention of if-then production rules and the use of a pattern recognition strategy. Well-structured knowledge facilitates the straightforward and correct interpretation of data for the testing of hypotheses, which is what experts have been found to do (Elstein et al., 1990).

The knowledge structures involved in the medical field appear to be important for the efficient identification of the correct diagnosis. Differences in the structure of the underlying knowledge-bases are also known to produce differ-

ences between experts and novices. In the medical field, Boshuizen (1989) has observed novices to use more causal (pathophysiological) models than experts. Experts use clusters of symptoms with their matching diagnoses and therefore work faster and more efficiently.

In the area of reading and spelling problems, studies with a focus on decision making are rather scarce. Kruizenga and Bus (1991) found that experts in the area of reading and spelling problems do not build up problem representations with experience but...

> "have to explore, just like beginners, all kind of child characteristics and context features"

(Bus, 1992, p. 273). However, according to Kruizenga and Bus, this does not mean that the knowledge lacks an elaborated network of concepts; the knowledge, rather, may be poorly organised. Bus (1989, 1992) showed infrequent agreement with respect to diagnoses and treatment recommendations between professional diagnosticians with even the same training in the domain of reading and spelling problems. In clinical practice, each diagnostician collects that information which can be assumed to provide a better understanding of the problem (for instance, dyslexia).

Knowledge structures contain and organise the minimum amount of relevant diagnostic information. By diagnostically relevant knowledge, we mean knowledge that provides clues to the nature and severity of the problem, its possible causes, and its treatment. It should be noted that the results of empirical research are not always applicable to an individual case. For instance, the fact that there are more children with reading problems than statistically expected (Dumont, 1990) has no diagnostic relevance for a particular case. In the identification of the relevant knowledge-base for the diagnosis of reading and spelling problems, the distinction between knowledge that must be secured and knowledge of little relevance is very important.

The specific knowledge structures can be determined by at least three different sources of information: substantive theories, procedural theories about the diagnostic process, and accumulated experience.

Substantive diagnostic theories ideally specify the dysfunctional behaviours together with the conditions and mechanisms responsible for the dysfunctional state and the repairment. Each of these components has its place in the structural network of the theory which presents by itself a schematic blueprint for theory-related knowledge. In the domain of dyslexia, our expert (Dumont, 1990; Ellis, 1984) applies an information-processing model that differs from for example, a neuro psychological model of dyslexia (Bakker, 1983; Bakker, Wilsher, Debruyne,

& Bertin, 1987). These substantive theories generate different blueprints with respect to the diverse components, and the diagnostician who adheres to a particular theory must keep in mind the specific components in assessing the client.

Substantive theories are one of the most influential and scientific ingredients in the diagnostic process, but by themselves they usually do not specify in which order the diagnostician has to collect his information or by which decision rule he can proceed in order to produce sound knowledge-based argumentation. Examples of analyses of the prescriptive structure of the diagnostic process can be found in Westmeyer (1972) and Jäger (1986). From this perspective, the knowledge format will preferably have the capacity to integrate substantive declarative knowledge into a prescriptive structure. An example in the domain of beginning reading and spelling is Van Aarle's (Van Aarle & Van den Bercken, 1992) computerised description of symptoms, syndromes, and hypotheses in a structure that fits in with the framework of the Diagnostic Cycle (De Bruyn, 1992).

Both substantive theories and procedural models are scientific tools to be applied in daily practice. The daily practice allows diagnosticians to accumulate knowledge from earlier cases to analyse a new case. Differences are to be expected in personal knowledge, and these differences are highly likely to produce differences in (some aspects of) the knowledge structures. As mentioned earlier, Bus (1989, 1992) showed that such differences between diagnosticians in the domain of reading and spelling indeed exist. Experienced diagnosticians also do not differ less from each other than from novices, even when they had the same training as a school psychologist.

1.3 Formal approaches for improving diagnostic practice

The fallibility of diagnostic decision-making in both process and outcome has prompted a search for remedies: education, training, replacement by normative-statistical models, procedural-prescriptive models, and expert systems. In the context of this thesis, we will only mention the formal approaches for improving diagnostic practice. We will briefly consider the normative-statistical and procedural-prescriptive models but devote greater attention to expert systems and the knowledge-based approach that are the focus of this thesis.

1.3.1 Normative and prescriptive models

Linear statistical models (Goldberg, 1970; Meehl, 1954; Sawyer, 1966) do not necessarily represent the steps within the diagnostic process and may not be particularly representative of human decision-making as a result. Schwartz, Griffin, and Fox (1989) point to three main deficiencies: they operate simultaneously (instead of considering the data sequentially), they are inflexible (instead of generating preliminary hypotheses on the basis of partial information), and they use different data than diagnosticians (continuous instead of categorical data). As Kleinmuntz (1990) points out, moreover, people generally prefer real human expertise over the expertise of a system that actually outperforms humans when it comes to high-risk decisions.

Other formal approaches have been developed to assist diagnosticians using a Bayesian paradigm to optimise predictions under uncertainty. Tools have also been developed within a decision-analysis approach. In addition, a prescriptive diagnostic model may be used to prescribe the ideal diagnostic problem-solving process. For example, De Bruyn (1992) proposes a model to avoid certain sources of error and make the diagnostic process more reliable and valid. Such a prescriptive framework can then be implemented in a computer-assisted diagnostic decision system (Van Aarle & Van den Bercken, 1992).

1.3.2 Expert systems in social science and health care

A knowledge-based system is an information system that uses human knowledge to give a comprehensive answer to a question. The knowledge base can consist of, for example, empirical associations between phenomena, handbook-like thoughts, policy rules based on a particular type of law, or general opinions on a particular topic.

An expert system is a particular type of knowledge-based system; namely, one that involves expert knowledge typically obtained from a single expert. Parsaye and Chignell (1988) define an expert system as follows:

> "An expert system is a program that relies on a body of knowledge to perform a somewhat difficult task usually performed only by a human expert The principal power of an expert system is derived from the knowledge the system embodies rather than from search algorithms and specific reasoning methods An expert system successfully deals with problems for which clear algorithmic solutions do not exist." (p 1)

The expert knowledge that is derived from a human expert for a knowledge-based system has been built up during years of training, education, and experience in the solution of problems. Expert knowledge consists of a relatively efficient

functional theory for the solution of a particular kind of problem in a restricted domain.

The terms knowledge-based system and expert system are often used interchangeably. As we have used the knowledge of a single expert, supplemented by a bit of information from colleagues, the term expert system will be used in the remainder of this thesis.

An expert system usually consists of declarative and procedural knowledge; the declarative knowledge is stored in a knowledge base and the procedural knowledge constitutes the so-called inference mechanism. To interact with the user, moreover, a user interface must also be available (Jackson, 1987).

In the medical sciences, expert systems for particular diagnostic tasks have been well developed. Examples are MYCIN for the diagnosis of blood infections (Buchanan & Shortliffe, 1984), INTERNIST for the (multiple) diagnosis of internal problems (Pople, Myers, & Miller, 1975), and, in The Netherlands, PLEXUS for the diagnosis of plexus brachial injuries (Jaspers, 1990) and MEDES, which is a prototype for structuring medical knowledge (De Vries Robbé, Beckers, & Zanstra, 1988).

In the social sciences, the development of expert systems started later. Examples of expert systems in the social sciences are automatised classification systems, which have been developed for learning disabilities (Ferrara, Hofmeister, Althouse, & Likins, 1988), behaviour disorders (Ferrara, Baer, Althouse, & Reavis, 1988), and intellectual handicaps (Giere, Williams, & Ferrara, 1988). More complete expert systems for diagnosis have been developed for the assessment of autism (Adarraga & Zaccagnini, 1992), dementia (Plugge, Verhey, & Jolles, 1990), the assessment and recommendation of treatment for reading problems (Balajthy, 1989; Colbourn & McLeod, 1983; McEneaney, 1992), sexual dysfunction (Binik, Servan-Schreiber, Freiwald, & Hall, 1988) and emotional crisis (Hedlund, Vieweg, & Cho, 1987). Other systems have been developed for recommendations regarding intervention in the therapeutic process: individualised educational plans (Parry, 1986), the recording and management of student progress (Ferrara, Baer, & Serna, 1986), and recommendations regarding brief family therapy (Goodman, Gingerich, & De Shazer, 1989).

In this thesis, we aim to describe the diagnostic process as it takes place during the concrete activities of the diagnostician in interaction with his client from the very beginning to the end (from intake examination to the diagnosis and the treatment recommendations).

In view of such a comprehensive diagnostic process, most of the expert systems in the social sciences have a rather restricted scope in that their aim is to cover only one or two specific tasks. One of the most frequently tackled tasks is

that of problem identification or classification, and the fact that knowledge-based systems have been developed in this field demonstrates the feasibility of a knowledge-based approach in the domain of diagnosis. An analysis of the feasibility of this approach for the specific domain of reading and spelling will be presented in the next chapter.

Chapter 2
Obtaining and structuring expert knowledge on reading and spelling problems

In the present chapter, we describe the various steps followed in obtaining and structuring the knowledge of our expert. In section 2.1, some considerations concerning the feasibility of the project are given. In section 2.2, the collection of the case data with the use of audio tapes is described. As a result of this, insight into the daily practice of the expert diagnostician is gained. In section 2.3, the analysis of the intake interviews using verbatim transcripts is described. As a result, an inventory of terms and activities for the domain is obtained. In section 2.4, the process of acquiring and analysing static domain knowledge is described. We went through 12 research interviews with the expert. And thus had a structured collection of domain concepts. In section 2.5, the acquisition and analysis process for the diagnostic tasks using the information from two research interviews is described. The subtasks are described and the final general inference structure is presented. Finally, in the last section, some concluding remarks are provided about structuring the knowledge of an expert in the field of reading and spelling.

2.1 Feasibility considerations

Undertaking the development of an expert system in an unconventional domain creates a number of insecurities. One may wonder, for instance, whether the domain lends itself to the use of current techniques for the development of expert systems. Are the problems not too big? To acquaint ourselves with potential problems in the modelling of the diagnosis of reading and spelling problems, we followed some suggestions from Buchanan et al. (1983) and Prerau (1985, 1989).

In the project at issue, only a few people have been working on the expert system. The expert who has co-operated in our work built up his expertise over almost 30 years and has written several books and papers on reading and spelling problems. Thus he satisfies one of the criteria mentioned by Prerau (1985): he "has built up expertise over a long period of task performance...", and "is capable of communicating his knowledge, judgement and experience and the methods used to apply them to the particular task". The expert consulted in the present project is not only familiar with the reading process but also with the diagnostic practice of reading and spelling problems. A number of associates working in close co-operation with the expert have been invited to participate in specific

parts of the project, and, in particular, the evaluation of the expert system. The other participants were the knowledge engineer (myself) and a programmer. The knowledge engineer was supported by a number of decision-making experts. The programmer had a background in social sciences and was trained in programming languages appropriate to the development of an expert system.

The financial resources for the project have been relatively limited: a rather small budget was available for the programming work (including the necessary resources). The knowledge engineer was able to work on the project full time for two years and a half. During this period the expert was continuously available.

A number of the features fundamental to the development of an expert system, as mentioned by Prerau, applied to the domain that was the focus of the project: a reliance on expert knowledge, expert judgements, and expert experience; the inadequacy of conventional programming techniques; the existence of experts; the need to characterise expertise in this domain; significant payoff for the completed system; and a fit between the goals of the project and the demands of the domain.

Other features characterising a suitable domain are: explicit teaching to novices, the existence of handbooks, the availability of (test) cases, and at least some agreement among the experts with regard to the correctness of the system's results (Prerau 1985, 1989). As to the latter aspect, we do not yet have a clear set of criteria for evaluating the diagnosis provided by either the expert or the system. Three necessary but perhaps not sufficient conditions for a good diagnosis are: accordance with recognised procedural standards, correct and adequate use of all available domain knowledge, and a match to a potentially effective treatment for the problem.

To solve a diagnostic task in the domain of clinical psychology, diagnosticians have been found to use mostly heuristics. These heuristics appear to have two functions: the completion of the imperfect domain knowledge and the control of the various steps in the diagnostic process. In the domain of reading and spelling problems a complete model or diagnostic algorithm simply does not exist, and the heuristics relied on by experts must be made explicit.

The diagnosis of reading problems consists of several tasks that must be solved subsequently by professionals and thus lends itself to the creation of an expert system. The input information for the task can be made available to the system using intake-lists, and the output can be produced in the form of a report.

2.2 Collecting case data

Case data were collected in order to gain insight into the daily practice of diagnosing reading and spelling problems. We observed the expert while working with an associate. In particular, we followed two cases in detail by recording the intake interview with the parents, observing and recording the assessment of the children, observing and recording the exchange of information between the various diagnosticians, and interviewing the diagnosticians at several points in the diagnostic process (after intake, after the assessment of intelligence, after the first day of assessment, and after completion of the assessment phase). In this thesis the term 'intake interview' refers to the actual intake activity performed by the diagnosticians; the interviews performed by the researcher in order to discuss the diagnostic work are referred to as 'research interviews' (there were 14 research interviews in all).

2.3 Analysis of verbatim transcripts of the intake interviews

Verbatim transcripts were made of the tapes recording the work-up of the cases. Three excerpts of transcripts are listed in Appendix B.

The following activities were isolated as central to the diagnostic process:

- examination of the responses to the intake questionnaire
- intake interview with parents
- preparation of test situation: formulation of hypotheses, selection of test instruments
- testing
- evaluation of test results
- construction of the diagnosis and a proposal for a treatment
- written report to parents
- discussion of the report with parents.

These activities are now illustrated by giving examples of concrete content matters.

The intake questionnaire consists of questions about family structure, earlier assessments, the reason for referral, strong and weak aspects of scholastic performance, attitude towards school work, the possibility of sleeping or eating problems, tiredness, troublesome behaviour and questions about the occurrence of reading, arithmetic, or language problems elsewhere in the family. The parents must also report any events during the pregnancy and birth that were out of the ordinary; and any problems in motor, language, or play development; and any

problems throughout the school history, particularly with respect to learning and behavioural/emotional development. Some additional questions are asked about relations to significant others, such as teachers and friends, and also about hobbies. The last questions focuses on the problems at hand: When did they start? What has been done? And by whom?

The intake interview proceeds from the problems mentioned by the parents following a checklist about the biological development, developmental problems, motor and sensorimotor development, visuo-spatial development, laterality, language development, school history, and heredity. The interview takes about one and a half hours. At the end of the meeting, a preliminary overview of the treatment possibilities is given and a new appointment is made for discussion of the assessment results and proposed treatment.

The preparation of the test situation consists of formulating hypotheses about the learning problems and their causes and then looking for suitable test and observation instruments.

The testing of the child takes approximately one full day and one additional morning. An assessment is made of intelligence, school performance tasks, motor, and sensorimotor functioning, visuo-spatial functioning, laterality, language skills, and personality. Some instruments are part of the standard operating procedure. These include the WISC-R (an intelligence test for children) and various reading and spelling instruments. Based on the problems reported by the parents, additional instruments may be selected for use (such as the 'Sociale angstschaal voor kinderen' when the child appears not to have friends at school).

The test results are evaluated on the same day, immediately after the assessment. All tests are scored, and the norms for reference groups are applied to interpret the scores. In addition, any potentially relevant observations are taken into consideration.

The construction of the diagnosis and treatment recommendation is based on a combination of all the information from the intake, assessment and observation.

The report, written to the parents, summarises the conclusions and provides useful recommendations. The completion of the report usually takes between one-half and one-full day. Parents are asked to read the report at home, and an example of a report is presented in Appendix A.

In a subsequent meeting with the parents, which usually takes another one to one-and-a half hour, the conclusions of the report are discussed and the treatment recommendations further specified by the diagnostician.

To obtain an initial inventory of the terms used during the diagnostic process, the verbatim transcripts of the intake interviews were first analysed. Each sentence was supplied with one of three categories of labels: a content label, a procedural label or a dialogue-technical label. Content labels indicate information about the subject at hand, namely the content of the interview. This might be a question about the child's sleeping habits:

> "How long does the child regularly sleep?"

Procedural labels indicate information about the reasoning process of the diagnostician during, in this instance, the intake. An example might be consideration of the child's habits, drawing a conclusion, and then checking this conclusion on the basis of other concrete information, like in the following remark:

> "You told me your child is not good at remembering the names of the other children in the classroom. Perhaps he has a language problem. How is his rhyming ability?"

Dialogue-technical labels indicate information about the way in which the diagnostician conducted the interview. The diagnostician might, for example, explain a particular solution, summarise a point, or provide support to the parents, for example:

> "You really had a hard time with your child, am I correct?"

These three different kinds of labels provide a substantial differentiation of the knowledge used by the expert diagnosticians. The labels with respect to content represent domain knowledge (the first layer of KADS, Breuker et al., 1987) while the procedural labels represent more inferential and task knowledge (the second and third layers of KADS). As already mentioned, the dialogue-technical labels were reserved for how the diagnostician conducts an intake interview. This pertains more to the issue of whether the interview is satisfactory to both the parents and the diagnostician. Do the parents feel comfortable and are they willing to share their problems with the diagnostician? Although a good diagnostician must certainly have acquired these skills, we do not consider them skills in need of computer implementation. For this reason, this category of information was not used further.

The content labels were used to identify the diagnostically-relevant domain concepts used in the intake interview. The expert had previously developed a checklist (Dumont, 1990) for interviewing parents in the course of his practice, and this checklist was compared to the verbatim transcripts of the intake interviews. In the accompanying box, the expert's checklist is shown.

Anamnese van lees- en spellingsprobleem (Dumont, 1990)

1 Naam, geboortedatum
2 Plaats in de kinderrij
3 Schoolgeschiedenis
4 Biologische ontwikkeling
  zwangerschap
  geboortecomplicaties
  kinderziekten
  lichamelijke ontwikkeling
  familiaire ziekten
5 Ontwikkelingsproblemen
  zindelijkheid
  eetgewoonten
  slaapgewoonten
  zelfstandigheidsontwikkeling
  spelontwikkeling
  vrije tijdsbesteding
  gedragsproblemen
  opvoedingsproblemen
  gezinsproblemen
6 Motoriek en sensomotoriek
  lichaamsschema
  vingerdifferentiatie
  coordinatie
  evenwichtsgevoel
  handvaardigheid
  schrijfmotoriek
7 Visuo-spatiele ontwikkeling
  onthouden van afbeeldingen etc
  visuele analyse, synthese
  ruimtelijke orientatie
  ruimtelijk geheugen
  visuele herkenning, herinnering
8 Lateraliteit praktisch
  linkshandig/rechtshandig
  ambidextriteit
  kruisdominantie
  scannen van links naar rechts
  temporale volgorde van links naar rechts
  intermodale functie
  binoculair dieptezin
9 Lateraliteit verbaal
  benoemen van links en rechts

Anamnese van lees- en spellingsprobleem (Dumont, 1990) (continued)

10. Taalontwikkeling:
    - fonologisch:
        - identificatie
        - discriminatie
        - analyse
        - synthese
        - combinatie
        - geheugenspan
        - seriële ordening
        - closure
        - rijmen
        - alliteratie
        - intonatie/klemtoon
    - morfologisch:
        - woordvorming
        - woordverbuiging
        - woordvervoeging
    - syntaxis:
        - lengte van zinnen
        - welgevormdheid van zinnen
        - geleding van zinnen
    - semantiek:
        - woordbetekenis vastleggen en oproepen
        - woordenschat
        - taalexpressie
11. Schoolgeschiedenis:
    - klasseverloop
    - schoolrijpheid
    - tijdstip van stagnatie
        - eerste drempel: begin eerste klas
        - tweede drempel: van 3e naar 4e klas
        - derde drempel: vreemde talen
    - eerder onderzoek
    - eerdere maatregelen
    - sterke punten in het leren
    - zwakke punten in het leren
    - werkhouding/motivatie
    - omschrijving van het probleem zoals het door de school gezien en ervaren wordt
12. Erfelijkheid

The words in the checklist are compared to the words and sentences used by the expert in the intake interviews with the parents, taking into account the effect of what the parents said. This comparison revealed two major results. First, certain facts were simply not probed in the intake interviews, although they were listed on the checklist. For example, childhood diseases, diseases occurring frequently in the family, the child's sense of balance, finger differentiation, visual-analysis and synthesis ability, cross-dominance, scanning from left to right, inter modal functioning, binocular stereopsis, and parts of the child's phonological, syntactic, and semantic abilities were not considered in the two recorded intake interviews. Second, some matters were discussed by the expert in the intake interview but not included in the checklist. This included matters of interest to the child and consideration of the child's attention span.

2.4 Acquiring and analysing static domain knowledge

Using the checklist of the expert and the content of the actual intake interviews we obtained a preliminary collection of relevant domain concepts. The choice of a further elicitation technique depends on the types of tasks that an expert must execute as part of his job and the kind of knowledge that must therefore be collected. Some of the tasks can occasionally be executed simultaneously with other tasks. For instance, an expert can be asked to *think aloud* while solving a difficult mathematical problem. For the identification of procedural knowledge the use of *verbal protocols* is recommended (Schraagen, Schaafstal, & Bogers, 1988; Slatter, 1987). Often, however, it is simply not possible to think aloud during a task. For instance, we can not ask a diagnostician to think aloud while performing an intake examination with the parents of a client. In this case, observation of the expert, retrospection or interviewing should be used to acquire the necessary knowledge. Neale (1988) identifies the following kinds of interviews: tutorial interview, focused interview, structured interview, laddered-grid technique, teach-back interview, and introspection. In a tutorial interview, the expert is asked to prepare a lecture about the main themes in the knowledge domain. In a focused interview, the topics are prepared by the interviewer but the interview takes the form of a normal conversation. The topics in the interview can be the identification of the goals and subgoals for a task, the presentation of facts and goals, the classification of the relevant concepts, and the description of the intermediate reasoning steps in the problem-solving process.

In a structured interview, the knowledge engineer tries to elicit all of the knowledge that may be necessary for the description of a particular domain

model. The laddered-grid technique is especially useful for the construction of a hierarchical domain model. Concepts from the particular domain of knowledge are presented to the expert, who then paints the hierarchical structure associated with the concepts by providing concrete instances of each concept and superconcept. The intake checklist from the expert turned out to be a natural and effective instrument for the elicitation of knowledge as it already reflected part of the domain structure. In order to obtain a more complete overview of the relevant domain structure, however, we set up three structured interviews (research interviews 1–3) with the expert to confront the expert with our findings and ask for the rationale behind his choice of concepts used during the intake. These interviews lasted from three quarters of an hour to one hour.

2.4.1 Checklist for the intake

The first interview concerned features that had not been formally addressed in the intake interviews, although they were mentioned in the checklist. The relevance of these features was questioned. In the second and third interviews with the expert, a set of standard questions was posed with regard to the remaining aspects of the checklist.

1. Why is this area relevant for the anamnesis of reading problems?
2. What is the relation between this aspect of the checklist and reading problems?
3. Which information do you need from the parents?
4. What is the relation of this aspect of the checklist to other aspects?
5. What exactly do you mean by this aspect of the checklist?
6. Give an example of a situation that illustrates this aspect of the checklist.

The first question is important to understand the relation between the problem area and the reading and spelling problems. We wanted to know whether a specific problem area represents the right track for identification of a cause for the problems. The second question specifies the relevance of a specific aspect for the diagnosis of reading and spelling problems. It is important to know whether an aspect of the checklist represents a cause for the reading problems, is correlated with other problems, or possibly caused by the reading and spelling problems themselves.

The third question addresses the information necessary to generate preliminary hypotheses with regard to the diagnosis and an efficient diagnostic process. Familiarity with the concurrent values for each aspect of the checklist is also needed. The fourth question is necessary to understand the relation between a particular aspect of the checklist and other aspects, for instance; does a hier-

archical relation or a correlational relationship apply? If one aspect is problematic, it is possible that another aspect is problematic too. The fifth question is necessary to further define a specific aspect of the checklist and discuss the differences between aspects that may look alike. The last question is useful for identification of concrete situations and validation of the relevance of the aspect under consideration. An excerpt from the second interview is presented in Appendix C.

2.4.2 The structure of the language domain

In structuring the domain knowledge we looked at several examples of how to chart a domain (Kuipers & Kassirer, 1984; De Vries Robbé, Beckers, & Zandstra, 1988). We began with the general language development of the child as this was a relatively well-demarcated subdomain and regarded as extremely important by the expert. All of the relevant concepts were first identified by two persons independently. Any differences were then discussed, and the concepts selected again together. A total of 144 concepts considered relevant to the development of language were identified (see Appendix D). Next, in structuring the domain knowledge extracted from the verbatim transcripts a lot of questions arose including the following: Is this a concept or does it define a relation? Is this a diagnostically relevant concept or not? And, is this an abstract or a concrete instantiation of a concept? The different kinds of relations between the concepts were then identified by selecting the relevant phrases and discussing them. The relevant phrases included 'is a kind of,' 'has the characteristic of,' 'caused,' 'is correlated with,' 'affects'. A relational hierarchy based on the 'is a kind of' relation was then developed. The degree of concreteness for a concept was the dominant criterion. In case of synonyms, moreover, the most widely accepted term was included and the other word dismissed. At the bottom of the relational hierarchy, the most concrete concepts were located (for instance 'repeating the sounds one by one', 'knowing the days of the week'). These were found to be concepts referring to the behaviour of children, parents, and teachers. This level of knowledge proved to be extremely important because it was the level at which parents and teachers communicated about a child's problems. In other words, this level of knowledge would be critical to the user-interface in our program.

The more abstract concepts were considered next. Some general concepts (not specific to language development, for instance 'writing', 'reading'), relevant to other subdomains, and some features subsumed under the concept of language development were considered. The latter mainly involved the abstract cognitive concepts (as opposed to concrete behavioural) used by the diagnostician to reason

about the child's problem(s) (for instance 'modulation of expression', 'receptive vocabulary').

2.4.3 The structure of the other subdomains

After building a hierarchical structure for the language domain, the other relevant subdomains were also analysed using the first two research interviews. A total of 11 subdomains were identified as particularly relevant to the diagnosis of reading and spelling problems. The subdomains are:

- physical functioning: for instance illness, physical development in the past, hearing, etc.
- motor functioning: movement, handwriting, bicycling etc.
- spatial orientation: knowing where to find something, orientation in space
- laterality: knowing what is left and right
- temporal sequencing: knowledge of event sequences
- visual perception: memory for pictures
- language: phonology, syntax, morphology, and semantics
- academic functioning: reading, writing, spelling, arithmetic
- cognitive functioning: memory, meta-cognitive processes such as monitoring
- personal functioning: motivation, temper, interest, shyness
- social functioning: interaction with parents, teachers, peers.

The subdomains corresponded fairly well to the areas outlined in the expert's original intake checklist. Appendix E shows all the subdomains identified and the hierarchical structures within the domains. In this appendix, some additional hierarchies are described that consist of two or three parts of several subdomains and together constitute a relevant abstract concept; for example the concept visual-verbal matching consists of a combination of semantics, phonology, visual perception and visual analysis and synthesis.

2.4.4 Diagnosis-related knowledge

In order to obtain the information needed to define the concrete relevance of the concepts for the domain structures, nine interviews were undertaken (research interviews 4-12). The topics considered in these interviews were as follows: An inventory of possible learning disorders (one interview), looking for particular values (yes/no) per problem area relevant for dyslexia (one interview), assessment instruments for the problem areas (four interviews: medical-neurological investigations and personality assessment, reading and spelling assessment, intelligence assessment, and functions assessment), criteria and symptoms for

dyslexia (one interview: for a brief overview, see Chapter 1), treatment principles (one interview), and specific values expected for the assessment aspects in case of treatment planning (one interview). All of the interviews took about two hours.

A handbook (Dumont, 1990) in which a large number of the assessment instruments are described was used to guide the four interviews concerned with the various assessment instruments. This handbook was also used in the elaboration of the various aspects of treatments to be discussed with the expert.

Verbatim transcripts were made of all the interviews. The content of all the interviews with the exception of those concerned with tests could be inserted into the existing hierarchical domain structures. An example of a completed domain hierarchy for the area of motor functioning is outlined in Figure 2.1.

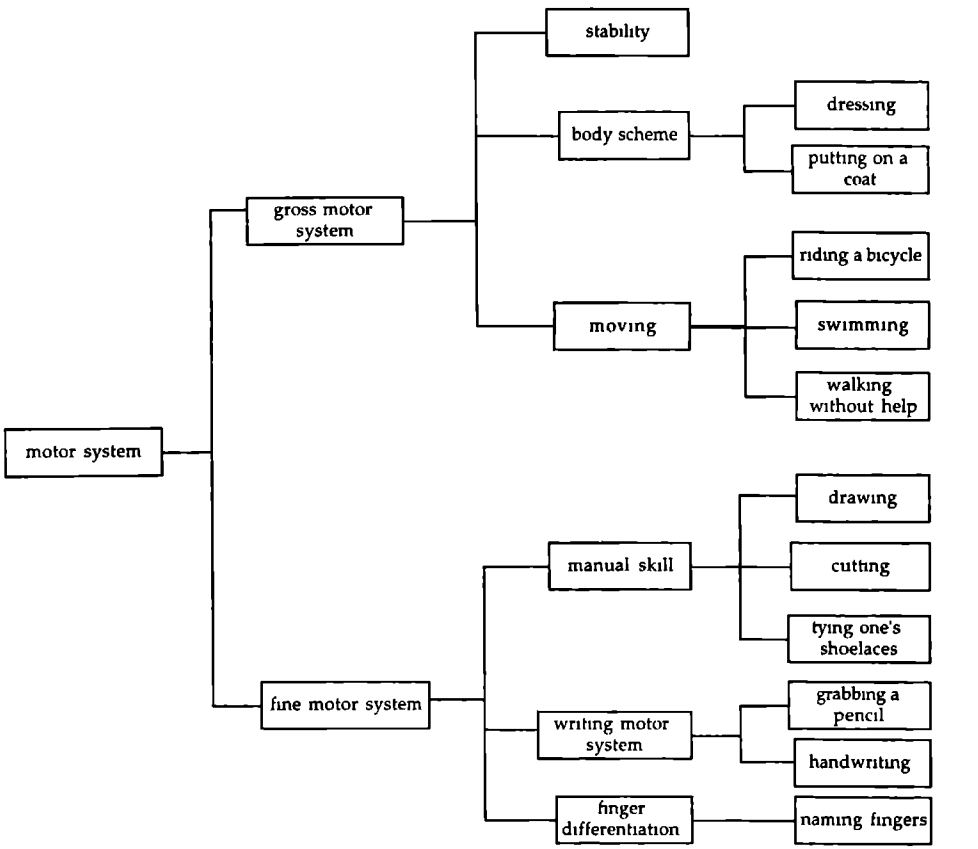

Figure 2.1 Hierarchy for the area of motor function

In Figure 2.1, the concept at the left represents the most abstract one (motor system) while the most concrete concepts are at the right. These concrete concepts are at the bottom of the hierarchy and represent the level at which the diag-

nostician communicates with the client or the parents of the client. The connection between the abstract and concrete concepts is provided by one or two intermediate concepts.

Each concept has a number of attributes that describe the relevance of the concept to the diagnostic process: the phase of the diagnostic process in which the concept occurs (intake, referral, assessment, further assessment, treatment); the kind of problem the concept may be symptomatic of; and comments that may be of particular relevance. Under 'assessment', moreover, whether the concept should be operationalised using a test instrument or observations is also specified. 'Treatment' is further divided into treatment methods and treatment materials. Any comments are implemented as logical expressions. An example of a concept follows in Figure 2.2.

	auditory memory	
phase:	assessment	
	test instruments:	Rispens: auditory memory
		WISC-R: digits
		LDT: repeating sentences,, vocabulary, retelling a story
		Termann-Merrill auditory subtests: ciphers, words, sentences, and stories
	observation aspect:	rehearsal
		chunking
phase:	treatment	
	method:	auditory training
	material:	Curriculum Schoolrijpheid IIA: auditory memory
symptom of:	dyslexia	
comments:	very important aspect; if auditory memory is a problem, the diagnosis dyslexia is becoming very likely	

Figure 2.2 The concept auditory memory with associated attributes

A separate structure was then created for all of the knowledge about tests (see Appendix F). Most of the tests are commercially available. Other tests are developed ad hoc by the expert for specific purposes. Of some tests only a few subtests are important for the assessment of dyslexia.

Any information pertaining to the diagnosis of dyslexia was structured as a logical rule in the form of 'if A and B and C ..., then criterion X is valid for this case'. The final set of decision rules is given in Appendix G.

An example of a rule:

rule dysharmonic intelligence profile:
if the score of the WISC-R verbal tests includes a score and
the score of the WISC-R performal tests includes another score and
the verbal score is less than the performal score
and the difference is more than 15 points
then the dysharmonic intelligence profile of dyslexia is true.

2.5 Acquiring and analysing diagnostic task structures

Apart from the relevant domain knowledge, the procedural knowledge used to complete the intake interview was also considered. The three verbatims of the intake protocols contained numerous procedural statements. Examples of these are:

drawing a conclusion:

"I think that auditory discrimination has to be assessed, because if this ability is not available for a child, this gives an idea of the severity of the damage to the phonological aspect "

"The structure is mostly a conclusion from concrete examples."

pointing to alternative hypotheses:

"Should I consider general behaviour problems, let's say hyperactivity, or is it a clear learning problem and, then, is it an arithmetic problem or a reading/ language problem? And if it is a reading/ language problem, will it become a case of dyslexia or a general reading/language problem?"

and comparing facts to a norm:

". . if children while using a pencil pierce through the paper, well yes, this might be a negative indication at the age of five, six years . "

2.5.1 Procedures and subtasks in the case work-up

In order to get a clearer picture of the specific task structure involved in the diagnostic process, two interviews were set up with the expert to discuss the procedural aspects of the diagnostic process (research interviews 13-14). In the first interview the expert himself described three major subtasks of an intake interview. These subtasks applied to the complete diagnostic process, from intake to advise. The first task was the delimitation of the problem areas. This task required the identification of the areas in which (e.g., language functioning, social functioning, perception) and the extent to which the child was having problems. The second task consisted of the establishment of a diagnosis, such as dyslexia,

Minimal Brain Damage, or some other learning disability. The third task was concerned with the 'individualisation' of the child's problems, which refers to the coupling of the problem description with an appropriate recommendation for treatment. The latter must be tailored to the child's personality in order to maximise the chances of success and thus depends on such things as motivation, attribution styles, and performance on other tasks.

Another, more general task, was found to occur in non-standard cases and consisted of coping with unexpected and/or inconsistent information, which may arise in every phase of the process of diagnosing.

In the second interview, examples of generic problem-solving tasks were discussed. First, a summary and examples were supplied to the expert about ways of problem solving in general (Breuker et al., 1987). Second, a summary of certain statements made by him during earlier interviews was presented to explore whether the expert agreed with our interpretations of his diagnostic activities in terms of more general problem-solving tasks.

The general inference structure during the intake interview appeared to be as follows: Data told by parents becomes relevant through activation of theoretical background information. This is probably a good description of the inference structure underlying the first task, namely the delimitation of the problem although a lot more takes place during an intake interview. For the other two tasks, namely proving dyslexia and individualising the treatment, an inference structure has yet to be set up. As we could not find a proper inference mechanism for the task of dealing with unexpected or inconsistent information, we simply paid special attention to this issue in the interview. The expert stated that for his work, two main input systems can be identified: first, the scientific literature; second, his experience with clients. Knowledge of the scientific literature is used in the diagnostic process and may be confirmed (or not) by the factual circumstances and findings with clients. The latter also constitute the basis for further literature search and research.

We decided to focus on the diagnostic tasks, identified as particularly relevant to the diagnosis of reading and spelling problems. The tasks are: (1) the delimitation of the problem area including identification of the problems and the extent of the problems; (2) the selection of a particular diagnosis: dyslexia, minimal brain damage, or some other learning disability; (3) individualisation of the problem and recommendation for treatment; and (4) coping with unexpected or inconsistent information.

2.5.2 *Inference models in the KADS library*

In order to model the four diagnostic tasks identified in the interviews with the expert, we consulted the library of interpretation models as originally developed in the framework of KADS (Breuker et al., 1987).

Four task models from KADS were thought to be potentially useful: heuristic classification, systematic diagnosis, assessment, and monitoring. We will describe each of them briefly.

The generic problem-solving task of *heuristic classification* appears to be a good candidate for the second task, namely the selection of a particular diagnosis. Heuristic classification requires a hierarchy of symptoms and a hierarchy of solutions, as provided by our data. After establishing an abstract description of the problem (for example, 'perception problems'), the two hierarchies can be matched using the criteria for dyslexia, as outlined in Chapter 1, or some other disturbance. At the same time the first task is also accomplished as the abstract description of the problem is virtually identical to the delimitation of the problem area. Heuristic classification can also serve as an initial model for the third task, the individualisation of the problem. However, a successful match is much more difficult for this task as the diagnostician processes an impressive amount of information in order to develop the best treatment plan for each individual child. Finally, the fourth task is by definition not heuristic as domain-dependent heuristic rules cannot be expected for the task of dealing with unexpected or inconsistent information.

The KADS *systematic diagnosis* (i.e., diagnosis by localisation and diagnosis by causal tracing) applies to domains in which part-of relationships (as with components of an engine) or causal relationships (as with pathophysiological processes) characterises the structure of the domain knowledge. The diagnosis of reading and spelling problems appears to rely predominantly on a kind of hierarchies. This means that systematic diagnosis in the sense of KADS is not particularly useful for the tasks identified as relevant to the diagnosis of reading and spelling problems.

The generic problem-solving task of *assessment* consists of abstracting a case description (e.g., from the data on a particular client) and specifying a norm for the behaviour in question (e.g., appropriate reading abilities) based on a system model (e.g., model of learning to read). The resulting metaclasses are then matched to produce an assessment. The KADS *assessment* appears to be a good model for our third task, namely the individualisation of the problem and provision of a recommendation for treatment. This process amounts to matching the individual profile of a child diagnosed as having reading problems with a treatment

plan based on a general model of learning to read (Dumont, 1990). Put differently: the general theory has to be tailored to the needs of the particular child and the proposed intervention strategies to be implemented by the specific teacher.

The final, potentially useful, generic problem-solving task is *monitoring*. Once again, however, this task does not directly apply to the process of clinical diagnosis. KADS *monitoring* refers to the classroom, where teachers are working with children and keep track of their ongoing performance and behaviour.

To summarise: For three of the four diagnostic tasks, a KADS model of a generic problem-solving task has been found to be potentially relevant. The first and second diagnostic tasks amount to *heuristic classification*, while the third diagnostic task was found to involve *assessment*. A model of the fourth task could not be found in the KADS library and will therefore have to be constructed from scratch.

2.5.3 *Inference structures of the various tasks*

Several types of domain-specific information are required for the successful completion of the tasks. We identified a number of the necessary inference structures through examination of the intake interviews. During this analysis, it became apparent that the inferences used in the second and third tasks, were also relevant for subsequent activities such as testing and observation of the child.

The first task (problem delimitation) is fairly easy to model by using the domain hierarchies constructed earlier. The task is performed by establishing the most concrete concepts and from there, then, activating continually higher concepts until one of the previously defined problem-areas is reached. The structure of the first task is shown in Figure 2.3.

```
FIND (DELIMITATION OF THE PROBLEM)
        GIVE VALUES (CASE DESCRIPTION)
        ABSTRACT (VALUED CASE DESCRIPTION)
```

Figure 2.3 The first task in the diagnostic process: Delimitation of the problem

Concrete behaviours or scores derived from the intake interview and the assessment phase were identified as 'problematic'. The values of the problematic concrete concepts were then projected into the more abstract concepts in the function hierarchies so that the more abstract terms would reflect the problematic value as well. For example, when a child of seven years still has trouble tying his shoelaces, this behaviour will be identified as problematic along with the abstract

concept 'manual skill'. As a result of this task, the diagnostician can see which function areas appear to be troublesome for the client.

For the second task (the selection of a diagnosis), we listed several attributes for the concepts in the hierarchies. The source of information could be an intake interview, a particular test, observation, neuro psychological examination, or medical-neurological examination. For the value of the information, this was the score for a particular test or observation. In addition, we constructed rules for coping with discrepancies in the information. For instance, a mother might say that something is a problem while tests showed it not to be. Finally, we constructed criteria for the establishment of a diagnosis and rules for how to deal with cases where the diagnosis of dyslexia do not apply.

In the second task or establishment of a diagnosis, the problems (symptoms) were compared (matched) to the criteria and characteristics of dyslexia and other possible causes of reading and spelling problems (the diagnoses). The structure of the second task is outlined in Figure 2.4.

```
ESTABLISH DIAGNOSIS
    FIND (DELIMITATION OF THE PROBLEM)
        MATCH (PROBLEM ABSTRACTION)
                SPECIFY( CRITERIA AND FEATURES)
```

Figure 2.4 The second task in the diagnostic process: Establishment of a diagnosis

The symptoms associated with the complete problem description (after abstraction) are first matched to the general criteria for dyslexia. Second, further criteria and features are considered if the diagnosis is not exactly dyslexia. A more general learning problem, minimal brain damage, or a reading problem secondary because of another problem can be present.

For the third task (the individualisation of the problem and recommendation for treatment), we use the extended case description generated for the preceding two tasks and designed a general treatment plan to tailor the profile to a particular child. The general treatment plan is combined with the hierarchical structures.

In the third task or formulation of an individualised treatment plan, the concrete behavioural aspects identified as relevant for treatment are initially abstracted. A match is then made between a generic treatment plan (which has been incorporated into the function hierarchies in the form of prerequisites and steps for learning to read and spell) and the relevant aspects of the case (problems, skills, and personality aspects). A specific treatment plan (methods and materials)

can then be generated based on the specific abilities and requirements encountered in the case. The structure of the third task is outlined in Figure 2.5.

```
FORMULATE INDIVIDUALISED TREATMENT PLAN
    OBTAIN (CASE DESCRIPTION)
        ABSTRACT (CASE DESCRIPTION)
            SPECIFY (RELEVANT PREREQUISITES AND STEPS)
                MATCH( ABSTRACTED CASE DESCRIPTION,
                RELEVANT PREREQUISITES AND STEPS)
```

Figure 2.5 The third task in the diagnostic process: Formulation of an individualised treatment plan

It was decided to omit the fourth task (coping with unexpected or inconsistent information) at this point and deal with the other three tasks alone. The implications of the decision to develop a knowledge-based system for 'standard cases' are discussed in Chapter 5.

2.5.4 *The overall inference structure*

The overall inference structure for the diagnosis of reading and spelling problems in standard cases is presented in Figure 2.6.

The central metaclass is the *case description* which is based on the data collected from a variety of sources. The three tasks are solved using heuristic inferences: abstraction and matching. Before the matching process can take place, an abstract inference takes place in which all related concepts are activated as being problematic. Two types of heuristic matching are then possible and depend on the type of data involved. The first type of heuristic matching occurs between the *problem abstraction* and the various *criteria or typical features* for each diagnosis. A *refinement of the diagnosis* then takes place after the matching. The second type of heuristic matching is between the *abstracted case description* and all of the cognitive elements instantiated as relevant to successful reading (*specific abilities and requirements*). Given the metaclass *system model* of learning to read and spell, the *abilities and requirements* must be specified according to the abstracted case description.

To conclude, the complete diagnostic task involves a combination of two inference structures: heuristic classification and assessment. Heuristic classification can be performed via two routes: forward chaining or reasoning from the data to a (refined) diagnosis, and backward chaining or proposing a diagnosis and then requesting the relevant data. Our diagnostician appears to use mainly forward chaining although discovery of missing information will prompt him to change

his direction of reasoning and request the relevant information. Assessment relies on forward chaining to process the complete profile of the client. From the data on a particular child, an abstracted case description is constructed to instantiate different levels of the problem hierarchies. The abilities and prerequisites that appear to be deficient in the abstracted case description are then identified. Proposals for remediation are derived from the system model of learning to read and spell. These proposals are then compared to the severity of the problems and other characteristics of the child in order to decide on treatment for each aspect of the problem.

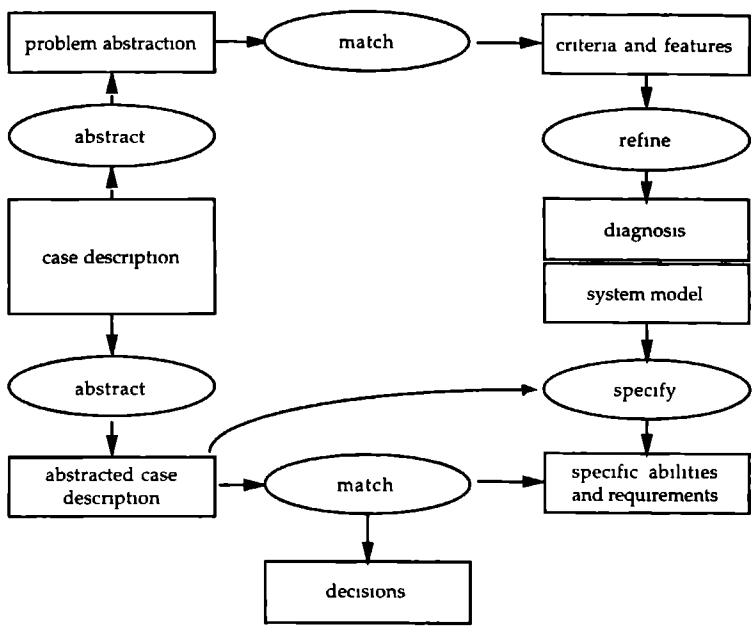

Figure 2.6 Inference structure for the diagnosis of reading and spelling problems [boxes represent metaclasses, ovals represent inference types]

According to our expert the output of the second subtask, the diagnosis, and the output of the third subtask, an individualised treatment plan, are not immediately related to each other. This is current practice in the diagnosis and treatment of reading problems. Whatever the cause of the problem may be, treatment is conducted in a more or less standard manner although in accordance with the severity of the problem.

2.6 Concluding remarks

A model of expert knowledge appropriate for being implemented in a computer program was the immediate objective of this chapter. The model itself was constructed in an (intuitive) way, and mainly based on ideas arising during the interaction with the expert and evaluated in discussions with the latter. The general KADS framework did not prove to be directly useful, particularly in the knowledge-identification phase. The interpretation models of KADS, however, were very helpful for the selection of the generic models of reasoning and appropriate domain attributes.

A difference was noted several times between what the expert expressed in the handbook (or other materials) and the actual use he made of such information. The actual practice of the expert was followed as the knowledge-elicitation methods used during the actual working process are presumably more valid than the knowledge extracted from the handbook. The information that is actually used during the diagnostic process is referred to as 'diagnostically relevant', and it is important to distinguish between information that *must* be used during the diagnostic process and information that can be seen as more background information in order to avoid an overload of information.

DYSLEXPERT is a minimal reproduction of the diagnostic reality of an expert in the domain of reading and spelling problems (and, in particular, dyslexia). This means that only the 'diagnostically relevant' information has been incorporated into the system. A lot of interesting information including the theoretical perspective of the expert, has not been included in the system. The domain knowledge has not been fully represented, it has been structured for a particular purpose: namely, diagnostic problem-solving.

The knowledge structures were defined from our point of view and need not be a perfect reflection of the expert's model of the domain.

We, for instance, set up eleven function areas that are not completely comparable to the function areas identified by the expert in one of his handbooks. In addition, we have structured the relevant knowledge into hierarchies. The expert does not appear to have such an explicit hierarchical framework in his head. From our point of view, however, this was an efficient way of representing the relevant knowledge.

Finally, the omission of the fourth task – namely, the ability to cope with unexpected or inconsistent information – must be considered. As already mentioned, the knowledge-based system developed here is for 'standard cases'. This is in part because the knowledge base is static and can not change with new expe-

riences in the way that human cognitive structures do. In addition, the system's reasoning is in terms of heuristic rules and therefore fairly fixed. A more hypothetico-deductive reasoning strategy, which was also detected in the diagnostic reasoning of the expert, has yet to be implemented. This means that the abilities of the expert have been reduced to an 'automatic reasoning mechanism'. Nevertheless, it is worth considering the results of such an expert system and then returning to this fundamental issue as will be done in Chapter 5.

Chapter 3
The program DYSLEXPERT

In Chapter 2, the activities involved in the knowledge-acquisition phase were described. In this chapter, the final results of the project are presented. The main implementation formalisms for the computer program DYSLEXPERT are presented by first describing DYSLEXPERT from the point of view of the user. The general structure will be presented together with an example of a typical session. Next the implementation details will be described with regard to the knowledge base and the processing of case information. Finally, some general comments will be made.

The model of expertise, as described in Chapter 2, was implemented in Prolog for the following reasons. We wanted to avoid the restrictions imposed by an expert system-shell on the particular inference mechanisms and be able to exploit the tools available in Prolog for the development of expert systems. For the implementation of an expert system, a variety of languages and tools is available: the traditional procedural (imperative) languages such as Pascal and C, descriptive (declarative) languages such as Prolog and Lisp (sometimes expanded with tool kits), expert system shells such as NEOMYCIN and ACQUAINT, and finally highly specific languages designed especially for the creation of knowledge-based systems. The actual choice of tool often depends on pragmatic factors: existing experience with a particular tool or the resources available for the development of the expert system. LPA MacProlog together with the Flex Expert System Toolkit (Vasey, 1989) appeared to be a suitable tool for our purposes. Flex provides frame-building tools, production rules, forward chaining, and a Knowledge Specification Language. Frame structures, the objects of the knowledge, are described in terms of attributes and specific values for these attributes. These frame structures are hierarchically structured. Production rules are cast in the form of logical propositions: if <antecedent> then <consequent>. If the antecedents in a rule are matched by the facts of a particular case, the rule will be executed and a consequent will be generated.

A programmer implemented the diagnostic process in chronological order with no explicit access to a representation of the domain knowledge. The knowledge engineer implemented the domain knowledge in frames and rules.

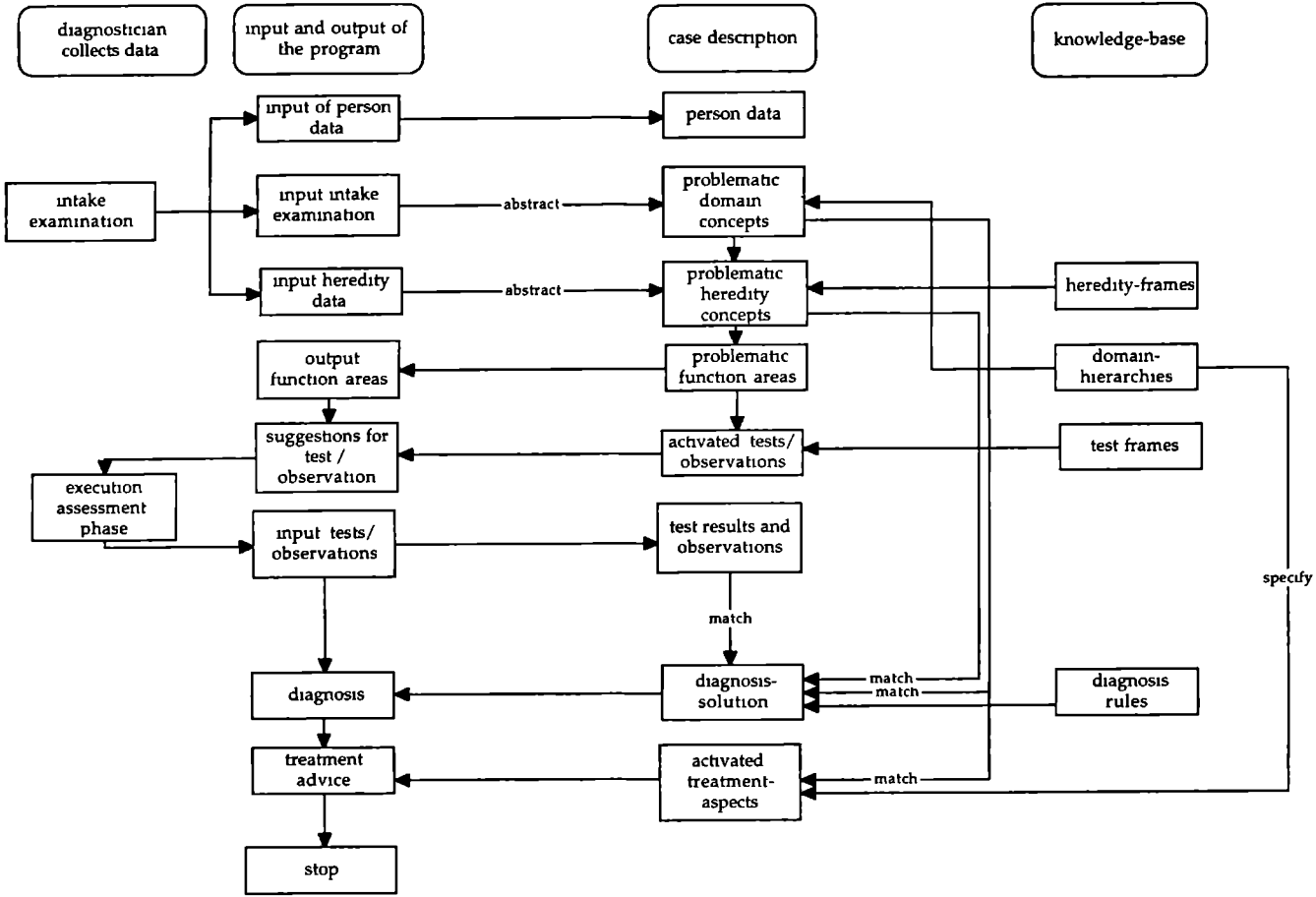

Figure 3.1 Overview of DYSLEXPERT

3.1 DYSLEXPERT from the user's point of view

3.1.1 General structure of DYSLEXPERT

An overview of DYSLEXPERT is presented in Figure 3.1. In this figure, the interaction is shown between the diagnostician and the program. The diagnostician feeds the computer with two inputs and, after processing the data, the computer produces four outputs. In the following, we will discuss the program from the point of view of the user (column labelled 'diagnostician' in Figure 3.1), describing a typical session with the system.

3.1.2 A typical session

The program is intended to be used after the completion of an intake interview with the parents of a child who has reading or spelling problems. When the diagnostician starts the program, a brief introductory text is presented as can be seen in Figure 3.2.

The program then asks for the person data represented in Figure 3.3 and for concrete problem behaviours. The latter may be selected from a menu of some 178 problem behaviours, as illustrated in Figure 3.4. Next, some information regarding hereditary factors is requested as illustrated in Figure 3.5.

Figure 3.2 Introductory text

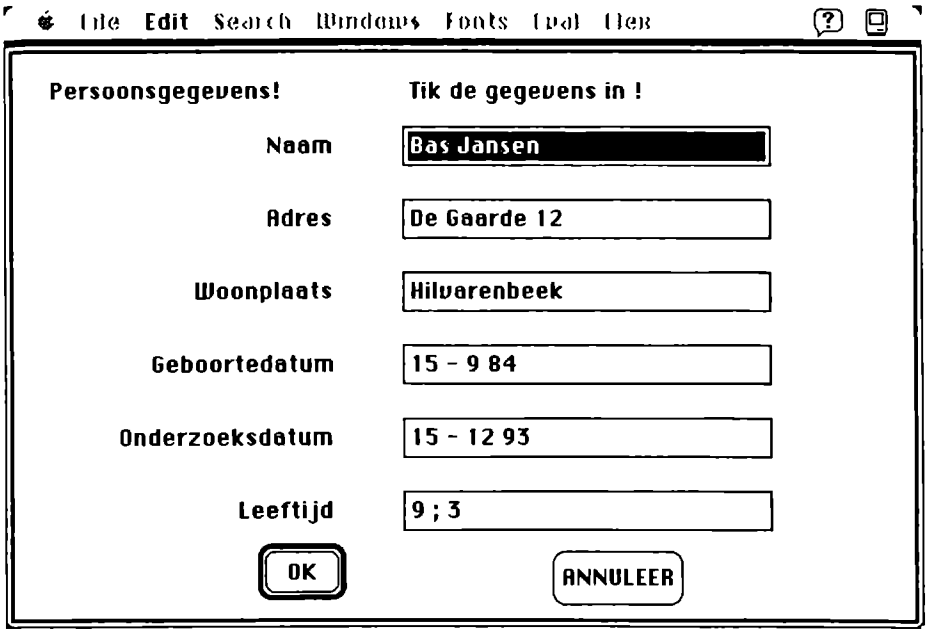

Figure 3.3 Person data

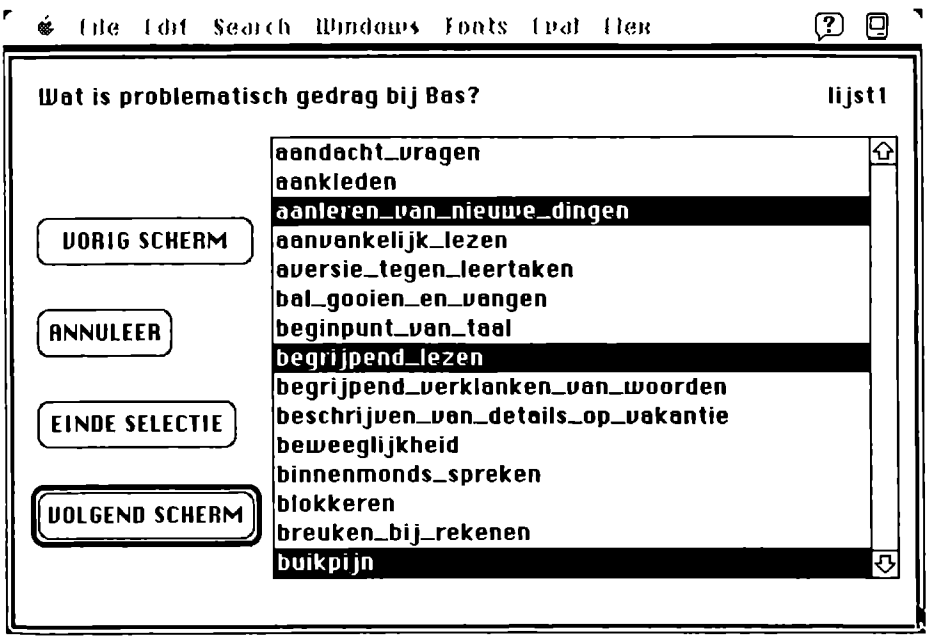

Figure 3.4 Concrete problem behaviours

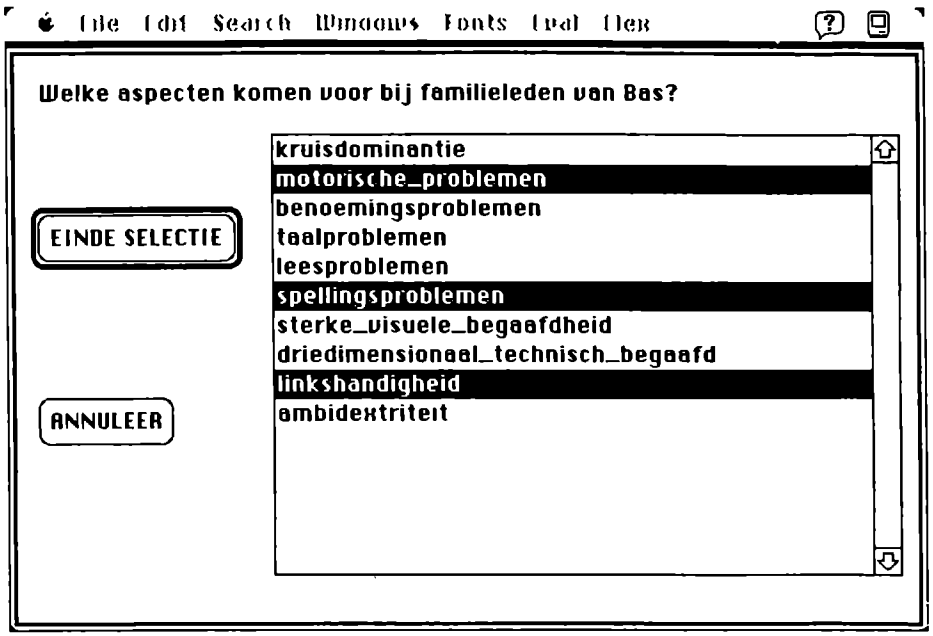

Figure 3.5 Hereditary aspects

DYSLEXPERT processes the intake information and produces a reaction. The first output from DYSLEXPERT is a list of function areas appear to be problematic. An example of a single area is presented in Figure 3.6. A selected problem behaviour activates higher hierarchical concepts and therefore activates the relevant problem area. The second output from DYSLEXPERT is a recommendation regarding further action: Just, what tests may be used to establish a diagnosis for the reading problems or other problematic behaviours (Figure 3.7 and 3.8), and what observations should be made during the assessment phase (Figure 3.9). In some cases, the program will also suggest further medical or neuro-psychological examination.

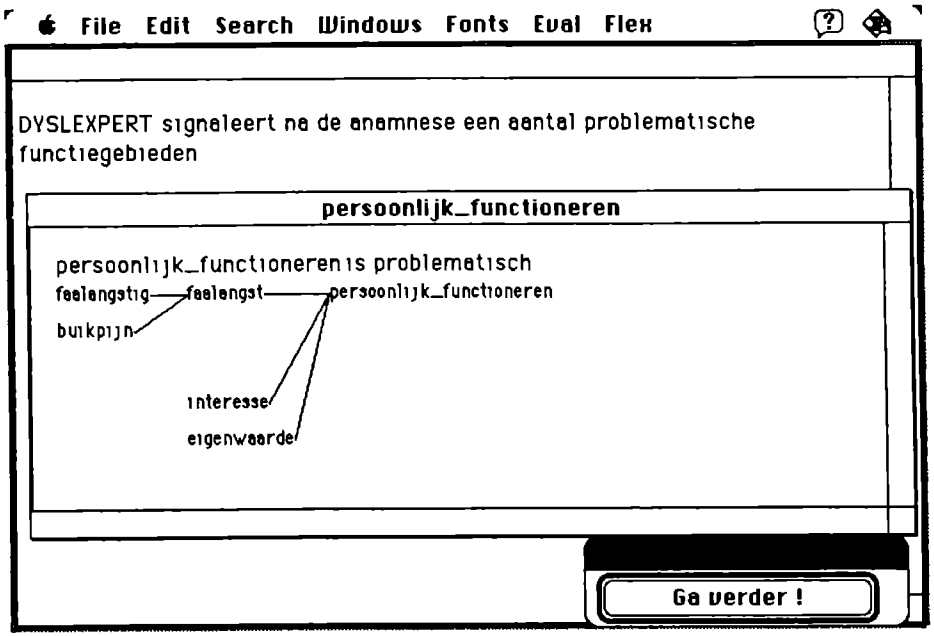

Figure 3.6 An example of a problematic function area

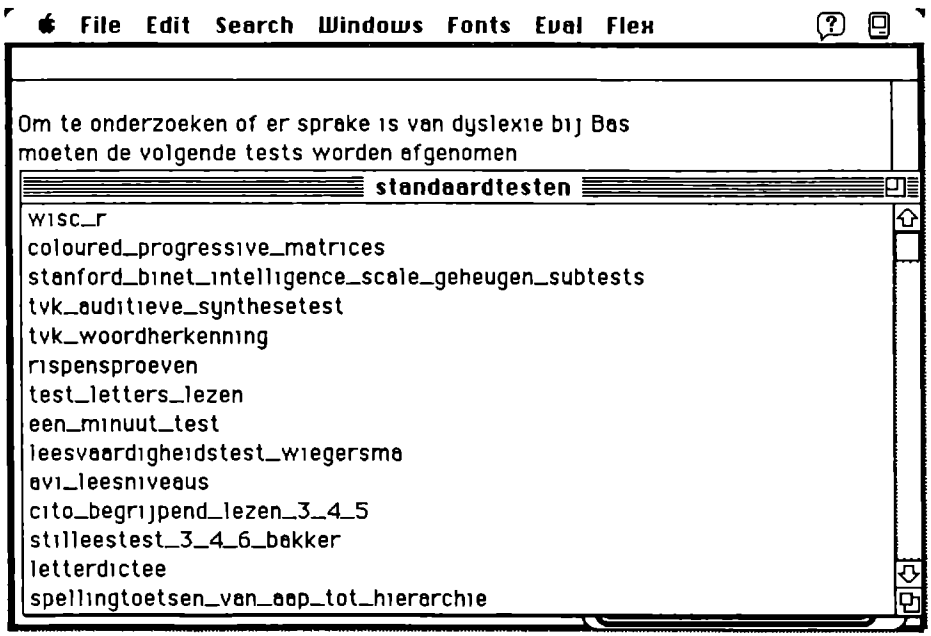

Figure 3.7 Recommendations for further action (standard tests to investigate the hypothesis of dyslexia)

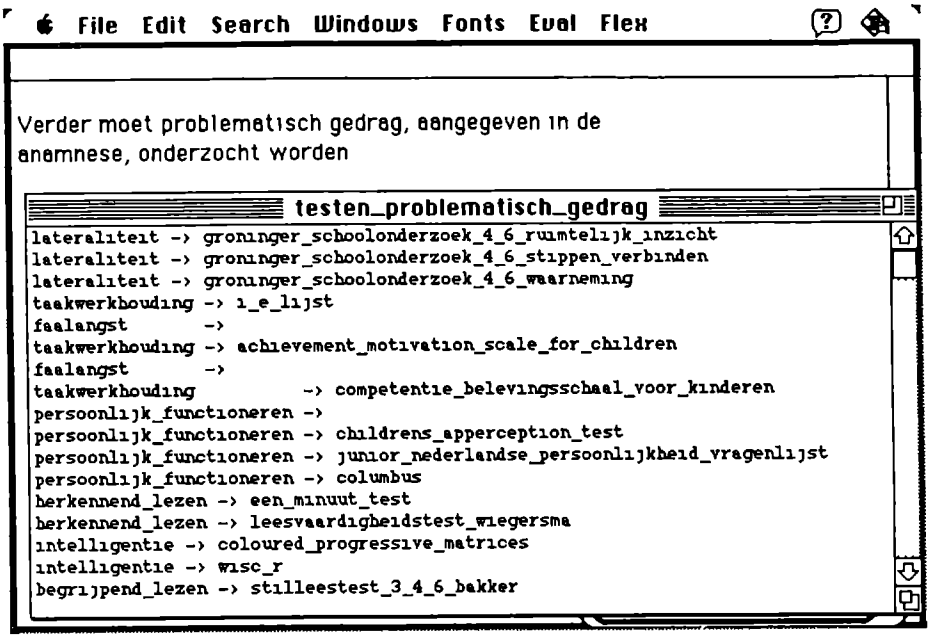

Figure 3 8 Recommendations for further action (tests for problematic behaviour)

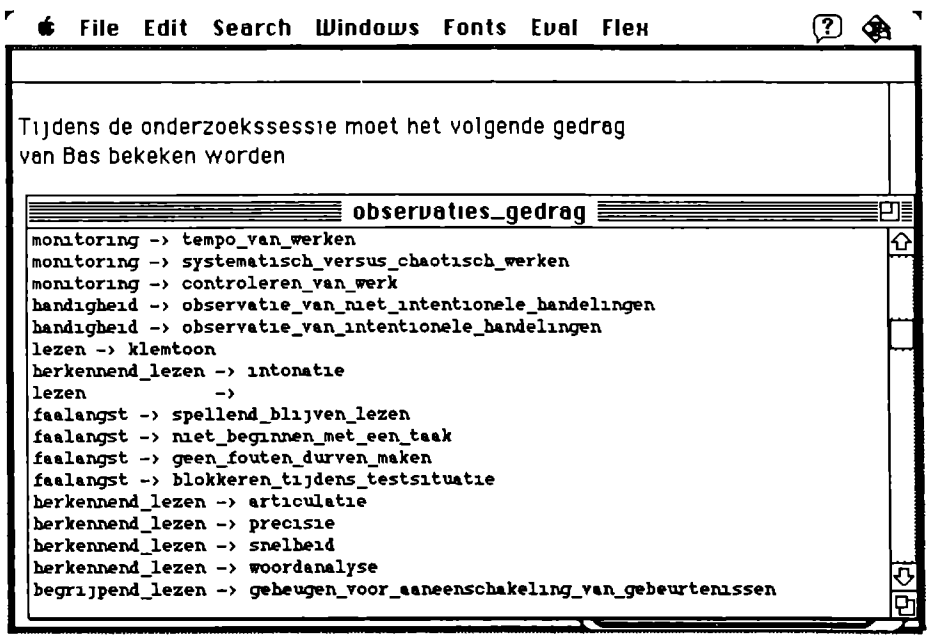

Figure 3 9 Recommendations for further action (necessary observations in the assessment phase)

The diagnostician then performs the recommended tests and interprets the scores. DYSLEXPERT requests this information, as illustrated in Figure 3.10 and 3.11. The program then combines this new information with the intake information and checks the seven criteria for dyslexia to formulate a diagnosis, which is illustrated in Figure 3.12. If there is not enough evidence for dyslexia, DYSLEXPERT provides cues for other diagnoses such as 'general learning disability' or 'minimal brain damage.' These conclusions are only hypotheses and not diagnoses as there has been no extensive formal evaluation of the alternatives.

DYSLEXPERT also provides a treatment recommendation as illustrated in Figure 3.13. This is done by screening all of the problematic concepts that have been activated for treatment cues. These cues take the severity of the problem and any secondary problems (such as fear of failure or motivation) into consideration and are presented to the diagnostician.

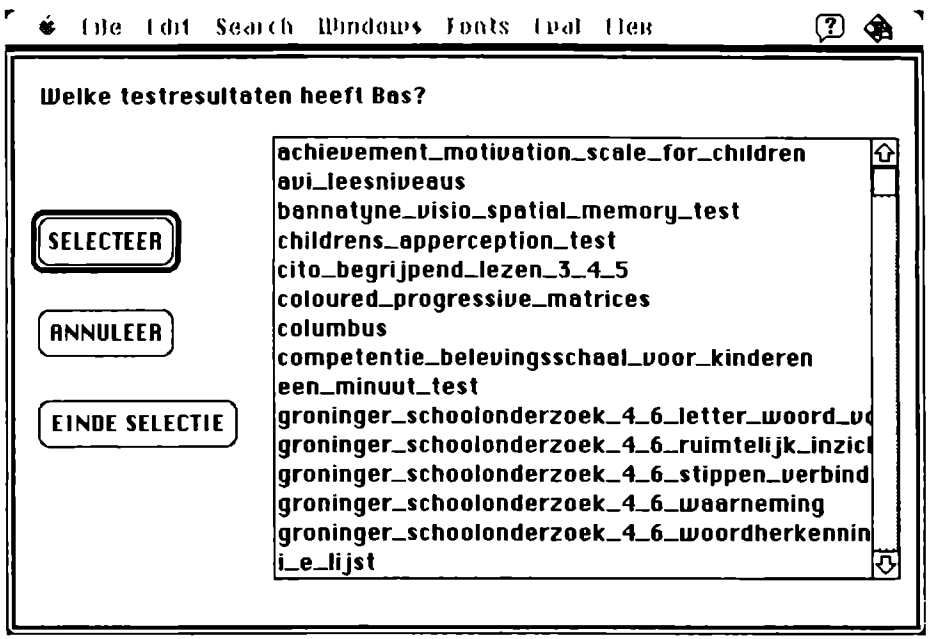

Figure 3.10 Entering the test results

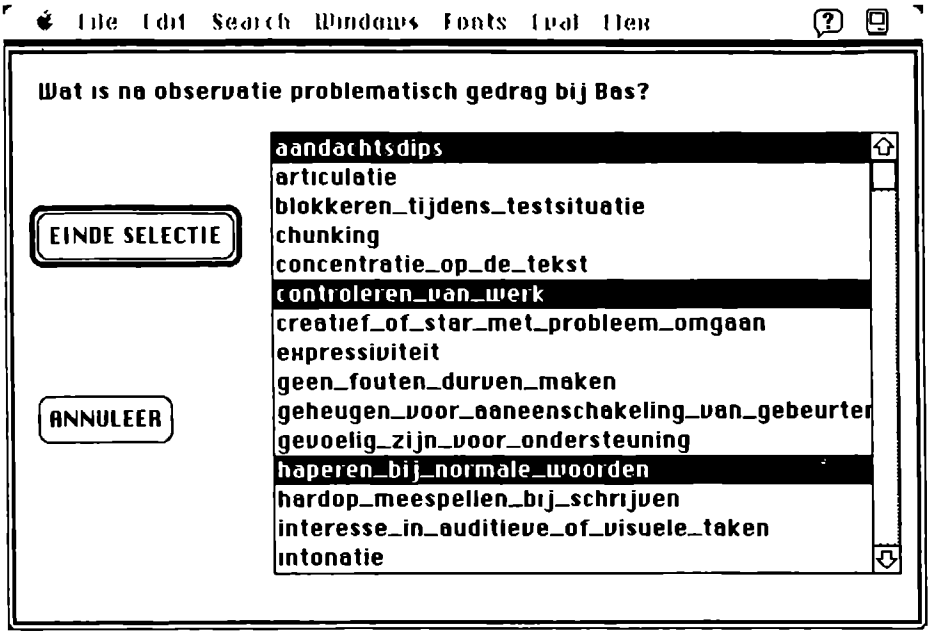

Figure 3 11 Entering behaviour observed as problematic during the assessment phase

Figure 3.12 The diagnosis

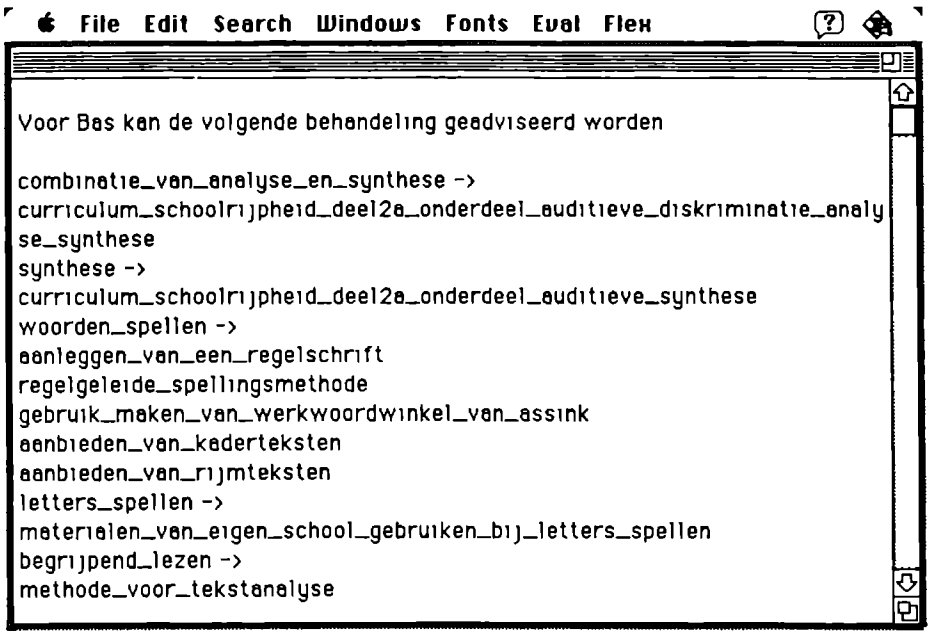

Figure 3 13 The treatment recommendation

3.2 Implementation details

3.2.1 The knowledge base of DYSLEXPERT

The knowledge base is built up as a collection of hierarchies of frames. An example of a frame is given below.

```
frame reading_of_text is a kind of reading;
    phases are { intake and test and observation} and
    tests are {avi_reading_level and kijkbewijs_henneman} and
    observation are {intonation and expression and tune_of_sentence} and
    treatment are { reading_by_turns and reading_aloud_together and
        reading_with_tape_recorder}.
```

Eleven domain hierarchies were constructed containing about 325 concepts for the relevant function areas. Further, 80 tests (some of them consisting of more then 10 subtests) are described in 160 frames containing characteristics, such as the age range, norms, and default achievement values for dyslexia. We also implemented frames to describe the hereditary information obtained during the intake interview in a separate module.

For deriving the diagnosis of dyslexia, we developed 15 domain rules that contained all of the values considered important to the diagnosis of dyslexia. The intake, test, and observation concepts all have default values for dyslexia (i.e. a value expected in the case of dyslexia). Seven rules describe the seven criteria for the definition of dyslexia. The remaining eight rules define the diagnoses (see Appendix G). The diagnoses are: 'This looks like dyslexia', 'This looks like dyslexia but the situation is complicated because of a few other problems such as hearing disabilities in the past or symptoms that can also match the diagnosis M.B.D.', 'This looks like dyslexia but there are also some secondary problems caused by the dyslexia. The problems are fear of failure, lack of motivation', 'This looks like a reading problem with an unknown cause and there are also other problems such as problems with math', 'This looks like dyslexia; nevertheless, no difference has been found between the visuo-spatial factor and the verbal factor. An explanation for this could be that the client is very sensitive to time-limited tasks and therefore the performal factor is suppressed', 'This doesn't look like dyslexia, but it is still a learning disability', 'This looks like a reading problem with an unknown cause', 'A diagnosis can not be given for this complex of problems'.

To solve discrepancies such as a test result below normal and an observation in which no problems were observed, some general rules were also set up. For instance, the test results are valued more highly than observations in making the diagnostic decision.

3.2.2 Processing case information

The case description is built up during the diagnostic process. A case name is provided by the person data. From concrete problem behaviours an abstraction is made to the relevant function areas, which may then be identified as problematic (see Appendix H). Heredity concepts are also identified as problematic. All of the activated frames point to further steps in the diagnostic process. The activated test frames also check the relevant age range. Recommendations are then made for the assessment phase, including tests, observations, and possible referral for further medical and neuro-psychological examination. When the diagnostician has completed the suggested examinations and computed the relevant test scores, these are added to the case description.

The derivation of the diagnosis is based on a heuristic classification process. The activated intake concepts, hereditary factors, test results, and problematic observations are matched using the heuristic rules for diagnoses (see Appendix H).

During the assessment process, a treatment recommendation is developed. The sequential structure of the domain hierarchies also includes a model of treatment (system model). The activated concepts generate attributes for treatment to the diagnostician (see Appendix H).

3.2.3 General comments

The process of developing DYSLEXPERT was guided by the KADS framework along with some common sense. The resulting system should be regarded as the outcome of a pragmatic knowledge-engineering process.

DYSLEXPERT diagnoses reading and spelling problems using qualitative rules such as the criteria for dyslexia. We have not worked out quantitative aspects of the diagnostic process such as uncertainty, and unreliability of the diagnosis or the relative importance of various concepts but we considered including such information. We found much of the problem solving in this domain to rely on qualitative rules involving purely yes/no decisions and therefore we decided to develop a system based on qualitative information first. In addition, we were simply unable to specify any useful quantities.

We are aware of the fact that the knowledge base has some redundancy. Because of the forward chaining process a large number of features and symptoms are presented to the user for selection. Those aspects that appear to be problematic are further assessed with test instruments and observation and only then is a decision made as to whether this all leads to dyslexia or not. There is an extensive check for dyslexia, but not for other problems that have yet to be fully implemented. This means that a lot of information remains behind without a conclusion as we were not interested in the entire area of learning problems.

During the development of DYSLEXPERT, we became aware that the inclusion of explanation facilities takes a lot and energy. In the present version of DYSLEXPERT, not all explanation possibilities are fully implemented. The program 'explains' its decisions regarding the problematic function areas with graphic representation of the instantiated hierarchical structures. The various treatment steps are 'explained' by enumerating the concepts they come from. A facility for the explanation of the causes and explanation of the recommended assessment instruments is still needed.

Additional information at the domain layer would also be useful. For example, it would be helpful to have files with definitions of the concepts used, the diagnostic relevance of the concepts, and the potential role of the concepts in the diagnosis of reading and spelling problems. Also, it would be useful to

present further information about the criteria for dyslexia and particularly useful assessment instruments.

In the following chapter, Chapter 4, the final evaluation in which the performance of DYSLEXPERT is compared to the performance of a group of human diagnosticians will be described.

In Chapter 5, a number of points discussed in the present chapter will be considered in light of the evaluation results.

Chapter 4
Evaluation of DYSLEXPERT: A comparison of a knowledge-based system with experienced clinicians in the diagnosis of dyslexia

4.1 Introduction

In the field of psychological assessment, computerised testing is becoming a matter of routine. The advantages are obvious: it saves time, presents a standardised testing situation, offers the possibility of feedback and adaptive testing, may have a lower threshold for clients, and ensures automatic storage of test results along with access to up-to-date norm groups (Carson, 1990; Nurius, 1990; Yokley, Coleman, & Yates, 1990). Computerised assistance in the diagnostic process itself, however, is less widely used.

During the last decade, several so-called expert systems or knowledge-based systems have been developed. These systems are computer programs that incorporate both the procedural and content knowledge from experts (Adarraga & Zaccagnini, 1992; Binik, Servan-Schreiber, Freiwald, & Hall, 1988; Plugge, Verhey, & Jolles, 1990). Such programs may be used as decision support systems. That is, the programs can be used to help clinicians decide on diagnosis and treatment. The advantages of such programs are: explicitly standardised procedures for the diagnostic process; the availability of recent knowledge about substantive problems, testing instruments, and treatment alternatives; and the provision of more general features such as explanatory facilities and the automatic storage of cases.

We have developed a knowledge-based system for the particular class of reading and spelling problems generally subsumed under the label of dyslexia. Dyslexia is nowadays generally regarded as a specific problem in reading and spelling, essentially consisting in erratic grapheme-phoneme conversions. As a consequence there may be a discrepancy between general cognitive and scholastic achievement and specific performance in reading and spelling. In clinical practice the problem of differential diagnosis is often dealt with by attempting to exclude rival explanations of the reading and spelling problems, like general intellectual impairment or sensory dysfunction. There is, however, no generally accepted view as to the causes and possible subtypes of dyslexia (Vellutino, 1978; Aaron & Malatesha Joshi, 1992; Van den Bos, Siegel, Bakker, & Share, 1994). The system, called DYSLEXPERT, is based on the knowledge of an expert in the pertinent domain (Dumont, 1990) and supplementary knowledge from his associates. The expert's working definition of dyslexia Dumont (1990, p. 41) is quite similar to the

following operational definition as recently proposed by the Research Committee of the Orton Dyslexia Society:

> "Dyslexia is one of several distinct learning disabilities. It is a specific language-based disorder of constitutional origin characterised by difficulties in single word decoding, usually reflecting insufficient phonological processing abilities. These difficulties in single word decoding are often unexpected in relation to age and other cognitive and academic abilities; they are not the result of generalised mental deficiency or sensory impairment. Dyslexia is manifested by variable difficulty with different forms of language, often including, in addition to problems with reading, a conspicuous problem with acquiring proficiency in writing and spelling." (Shaywitz, Fletcher, & Shaywitz, 1995, p. 51).

The work started as a feasibility study, intended to discover how artificial intelligence might be used to model and improve the process of diagnostic decision-making. As will be seen, we now have a knowledge-based system that performs at the level of experienced diagnosticians. After a brief description of the system, DYSLEXPERT, we will present a detailed report of its evaluation.

4.2 The diagnosis of dyslexia

The diagnosis of dyslexia usually involves three phases: an intake examination, focused assessment activities, and a decision procedure resulting in the diagnosis and a treatment recommendation. The entire process usually takes some 10 to 14 hours of work, and the majority of this time is spent in the administration of the tests.

As five to ten percent of the child population in the Netherlands manifest severe reading and spelling problems, the assessment of dyslexia is a fairly common professional task. The occurrence of dyslexia and thus its diagnosis also have serious consequences for the child. Reading and spelling problems can be a real barrier to a normal school career and often persist into adolescence (with the learning of a second language) and adulthood. At various stages in a child's school career therefore, diagnosticians may be consulted to give advice about how to deal with the problems.

The diagnosis of dyslexia is seriously hampered by the fact that even the experts do not agree on what the procedures and the substance of a diagnosis should be (e.g., Bus, 1989). This disagreement is not only a consequence of different theoretical backgrounds and varying degrees of practical experience but also inherent limitations on human judgement (e.g., Kleinmuntz, 1990). DYSLEXPERT may help overcome some of these problems by providing standard procedures and valid knowledge. We will not go into the development and structure of the

program here (Blonk & Van den Bercken, 1991, 1993) but concentrate on the way in which the program has been evaluated. For this purpose, it is sufficient to understand the way in which DYSLEXPERT functions in co-operation with the diagnostician.

4.3 The functioning of DYSLEXPERT

In Figure 4.1, the various functions of the program DYSLEXPERT are presented.

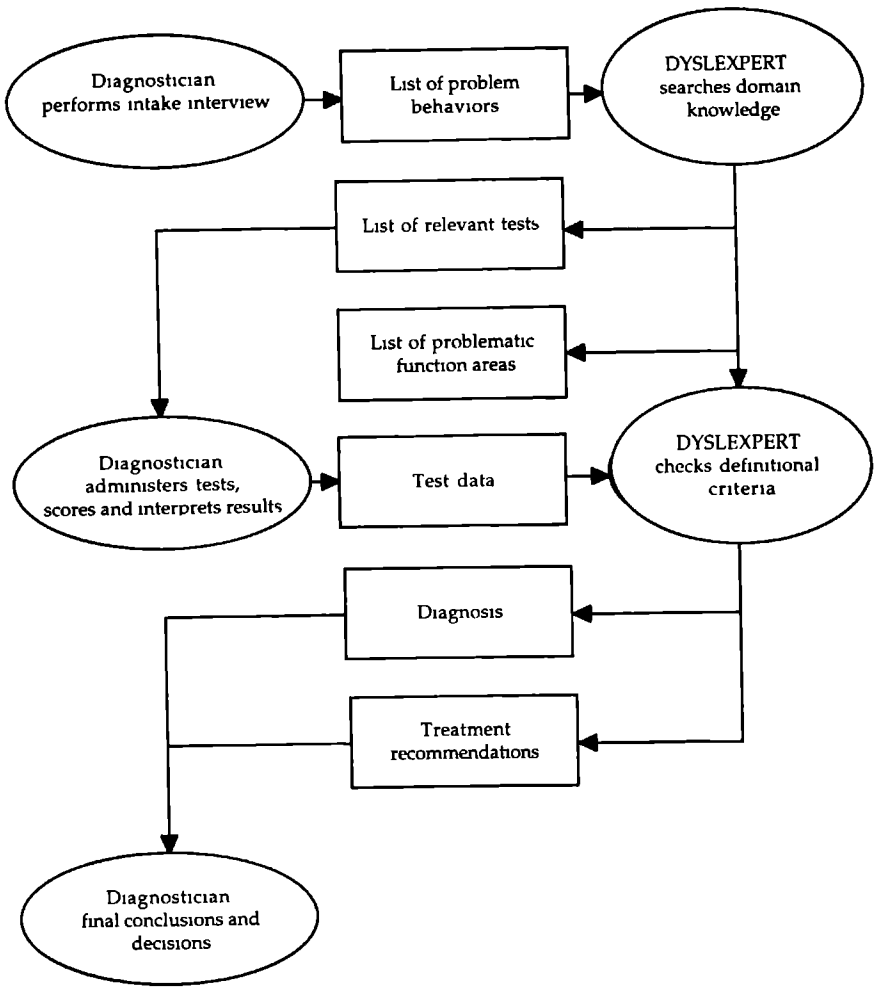

Figure 4.1 Interaction between a clinician and DYSLEXPERT in the diagnosis of dyslexia. Oval boxes represent the activities to be performed, rectangular boxes represent the results of these activities.

The clinician starts the diagnostic process with an intake interview with the parents of the client as the latter is usually a child. The information from the intake consists of personal data from the child, a list of concrete problem behaviours, and some facts related to hereditary conditions. This information, which is usually processed by the diagnostician only, may then be fed into the program by selecting items from various menus. DYSLEXPERT uses its knowledge-base to produce two kinds of output. The first type of output is a list of the areas of problematic functioning. The child may, for instance, have problems in the area of language functioning, motor functioning, and personal functioning. The second type of output is advice regarding further action for the diagnostician. This involves a list of tests that can provide the information required for a diagnosis of the reading and spelling problems along with suggestions for behavioural observation during the assessment phase. In certain cases, the program will also suggest further medical or neuro-psychological examination.

The clinician next administers the relevant tests, interprets the scores, and feeds these test results into DYSLEXPERT. The program then combines this new information with the intake information. By means of various heuristic rules, the program attempts to establish a diagnosis: dyslexia or not. If there is not enough evidence for dyslexia, the program provides cues for other diagnoses such as 'general learning disability' or 'minimal brain damage'. These conclusions are only tentative, however, as no formal evaluation of these diagnoses has been undertaken. In the case of dyslexia, the program also provides treatment recommendations, based on the problem areas that have been identified, the severity of the reading problems, and possible secondary problems (such as fear of failure or motivational problems).

From the present description, it should be clear that DYSLEXPERT is a modest knowledge-based system intended to support and not to supplant the human diagnostician. The program answers the same questions that have to be answered by human clinicians: Which areas of functioning are problematic? Which tests can provide the relevant information? Are we dealing with dyslexia? And how can the specific reading and spelling problems best be alleviated? The program includes those activities that are essential to the diagnostic decision-making process: it searches a knowledge-base to classify the observed problem behaviours from the perspective of dyslexia, establishes the diagnosis of dyslexia by checking definitional criteria, and specifies a treatment plan.

4.4 Evaluating the performance of DYSLEXPERT

The final step in the development of a computerised decision aid is to evaluate the effectiveness of the program in clinical practice. The most straightforward strategy would be to compare the output of the system with an indisputable criterion or the 'right solution' for a particular case. As O'Leary (1987) points out, however, expert systems have been largely developed in domains where unanimous agreement on the correct solutions does not exist. In the domain of reading and spelling problems, it is virtually impossible to draw upon a set of clear-cut cases or reliably validated diagnoses and effective treatments. In addition, human experts often do not agree with each other (or with themselves, for that matter) (Bus, 1989, 1992; Kleinmuntz, 1990). According to O'Keefe and O'Leary (1993)

> "(...) absolute validity based upon accuracy of solutions is a myth. The intended use of a model must be taken into account" (p. 6).

For this reason, O'Leary (1987) proposes the use of inter-expert agreement with experts from the same 'school of thought' as a viable way of validating an expert system.

4.4.1 Method

In view of the problems mentioned above, we decided to use an approach that differs from the usual one used to evaluate expert systems. First, we used a group of clinicians rather than a single expert as the standard of comparison for the diagnostic capacities of the system. Second, we took the inter-judgement agreement between the diagnosticians as the baseline for evaluation of the program. The program has to be as good as the diagnosticians for the same cases. Finally, we did not just compare the diagnoses of the clinicians with those of the program; some intermediate steps in the reasoning process along with the final treatment advice were also compared. The general validity of the system was checked with respect to the four questions listed above, and it was assumed that – given performance at the level of the human diagnosticians on this front – the program will beat humans with regard to such aspects as speed, utilisation of stored information, consistency, and reliability.

4.4.1.1 Subjects and cases

Four diagnosticians who have been working in a private practice for more than ten years in close co-operation with the expert on whose knowledge the program is based took part in the evaluation study. Forty cases were selected from their files: 20 cases of dyslexia and 20 cases of non dyslexia. Both sets of cases showed

reading and spelling problems while the cause of the problems was found to be something other than dyslexia in the non dyslexic group. The cases in the dyslexic group (18 boys and 2 girls with a mean age of 9;11 years) were previously used in a treatment evaluation study (Dumont, Oud, Van Mameren, Schoehuizen, Jacobs, Van Herpen, & Van den Bekerom, 1990). In this previous study, the subjects were screened by a group of diagnosticians for dyslexia using the criteria of an expert (Dumont, 1990). The non dyslexic cases (15 boys and 5 girls, with a mean age of 11;0 years) were selected for the present study using the following criteria: (1) reading or spelling problems were encountered, other problems minimally represented (2) the diagnostic criteria for dyslexia applied, and (3) the files contained the information necessary for comparison, including the areas of problematic functioning, the assessment instruments, the diagnoses, and the treatment recommendations. The dyslexic cases were examined between 1986 and 1990 while the non dyslexic cases were examined between 1988 and 1992.

4.4.1.2 Pre-processing of the cases for DYSLEXPERT

The relevant cases must be structured in a uniform manner in order to be entered in the program. The following information was selected from the files: (1) the core results from the intake interview including the problem(s) in question, any developmental problems, and information about similar problems elsewhere in the family; (2) the areas of problematic functioning; (3) the assessment instruments used during examination of the case; (4) the results of the assessment procedures; the interpreted test-scores, and observations; (5) the diagnosis of dyslexia or something else; and (6) the suggestions for treatment as outlined in the case report or a separate treatment plan. Items (1) and (4) constitute the input information for both the diagnosticians and the program. Items (2), (3), (5), and (6), or the answers to the four questions mentioned above constitute the results for comparison of the diagnosticians and the program.

The selection of the input information was checked by having a second person define the relevant input for items (1) and (4) in four cases. The inter-observer agreement varied between 71% and 100% for seven of the eight possible comparisons with the selection of the intake information proving quite unreliable (35% agreement) in one case.

All personal data with the exception of the child's age, which is necessary for the selection of the correct assessment, were omitted from the input data. The intake information was then described in terms of a limited vocabulary for about 180 concrete problem behaviours that had been identified during the knowledge acquisition phase of program development. The behavioural descriptions and assessment instruments that were actually used in the cases were listed. To be

able to compare the results of the diagnostic process for the diagnosticians and the computer program category systems were developed. The output could be compared in 12 categories for the problematic function areas, 130 categories for the assessment instruments, 2 categories for the diagnosis of dyslexia or not, and 14 categories for the treatment suggestions. The category systems are listed in the Appendix I.

4.4.1.3 Design

As outlined in Figure 4.2, the same set of cases was processed several times: the first time by human diagnosticians preceding this study (D1), the second time especially for this study by human diagnosticians (D2), and the third time also by the program DYSLEXPERT (P).

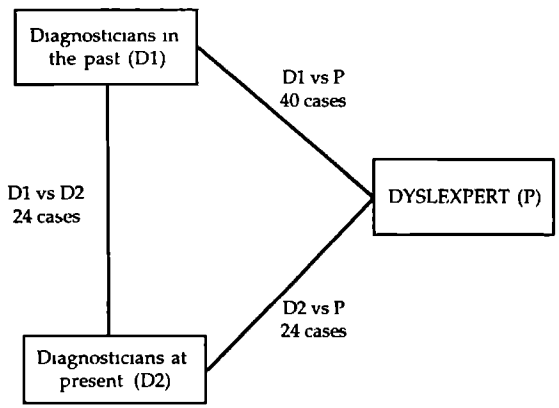

Figure 4.2 The design of the evaluation study. The comparison of D1 and D2 provides a baseline for comparing P to D1 or D2

This means that performance can be compared in three ways. To start with, the first and second processing by the human diagnosticians (D1 versus D2) can be compared to produce both intra- and inter judge agreement scores. This comparison provides the lowest acceptable level of correspondence between human diagnosticians and the program. Next, the original processing of the cases with the results of the program (D1 versus P) can be compared as indicated in Figure 4.2. Finally, the second processing of the cases by the diagnosticians can be compared with the results of the program DYSLEXPERT (D2 versus P).

The comparisons D1 versus P and D2 versus P have each their own advantages and disadvantages. The comparison D1 versus P has the possible disadvantage that it involves a comparison of the results of real diagnostic activities and procedures, on the one hand, with a more artificial paper-and-pencil represen-

tation, on the other hand. Precisely the fact that D1 has more ecological validity and may be more reliable than D2, however, also represents an advantage of the D1 versus P comparison over the D2 versus P comparison. In D1, a great deal of time is spent gathering information, thinking over various aspects of the case, and writing an extensive report. In D2, decisions are based on a condensed case description and made within a few hours. Another possible disadvantage of the D1 versus P comparison is that there may be differences between the more recent expertise of the program and the possibly less mature views of the diagnosticians. The comparison D2 versus P represents the most recent decisions of the diagnosticians. The program also incorporates the most recent views of an expert whose views are familiar to the diagnosticians.

In general, we prefer the comparison D2 versus P because the information involved and the procedures followed were basically the same for both the diagnosticians and the program; they both relied on the same information extracted from the same original files.

4.4.1.4 Procedure

The 40 original cases were all fed into the program, and 24 of the cases were presented to the four diagnosticians who participated in this study. Six cases per diagnostician turned out to be a fair compromise between our desire to have as many cases reworked as possible and not overtaxing the eagerness of the subjects to co-operate. The intake information was presented to the diagnosticians who were then asked to note the areas of functioning in which the child's problems could be located and which tests they would recommend for assessment. Similar results were provided by the program. When the program suggested assessment instruments that were not originally used, it was allowed to proceed by supplying default scores for these tests, such as 'average' or 'normal'. Subsequently the scores from the tests, administered in the assessment phase, were presented to the diagnosticians who were then asked to make their diagnosis (dyslexia or something else) and their recommendations for treatment. Similarly, DYSLEXPERT printed a diagnosis and recommendations for treatment.

As the cases were taken from the files of the diagnosticians themselves, we used the following presentation scheme. Each subject received three cases of dyslexia and three cases of non dyslexia. One of the cases of dyslexia had been examined by the diagnostician in the past while the remaining two had been processed by a colleague. Similarly, one of the cases of non dyslexia was previously examined by the diagnostician while the other two had been dealt with by a colleague in the past. Such a design allowed us to establish the degree of agreement between

the original and subsequent analyses of the cases, for the same and different diagnosticians.

4.4.1.5 Data analysis

The conclusions from each diagnostician and the conclusions from the program can be regarded as the output of independent raters. The relative frequencies of identical versus different decisions may be analysed using a consistency measure such as the kappa statistic (Cohen, 1960). The overall proportion of agreement and the associated kappa were used for the problematic function areas, the diagnoses, and the treatment recommendations. For the assessment instruments, the measure of specific agreement as proposed by Dice (see Fleiss, 1981) was calculated. This is because the number of instances of not selecting an assessment instrument was extremely large. Many instruments were simply unsuitable for a particular client on solely formal grounds, such as age, which would artificially inflate the agreement scores when the overall proportion of agreement and its associated kappa were used.

The differences between the kappas were statistically tested using the procedure developed by Fleiss (1981).

4.4.2 Results

The aggregated agreement data for the various comparisons are presented in Table 4.1.

The body of Table 4.1 consists of 12 contingency tables reporting the agreement between the diagnosticians' first and second case work-up (column labelled D1 vs D2), the diagnosticians' first work-up and the program's results (column D1 vs P) and between the diagnosticians' second analysis and the program's results (column D2 vs P). The agreement concerns the decisions made by each party with respect to the function areas as being problematic or not, with respect to particular tests as being useful for further assessment, with respect to the diagnosis of dyslexia, as being present or not, and with respect to particular treatment possibilities, as being a potential help or not. In each contingency tables there are four cells, identified by a row code (1 or 0) and a column code (1 or 0). The numbers in each cell refer to instances of agreement or disagreement. For each contingency table the marginal frequencies are given too. For example, in the D1 vs D2 comparison with respect to function areas, the diagnosticians initially reported 118 instances of problematic function areas (marginal frequency of row 1); in their reanalysis of the cases they reported 144 positive instances (marginal frequency of column 1). The number of decisions that were identical in both work-ups is 102,

as shown in the cell identified by row code 1 and column code 1. Out of the 118 decisions that were positive at the first analysis, 16 became negative at the second analysis.

Table 4.1 Agreement between the first and second analysis of the cases by diagnosticians (D1 and D2) and the program DYSLEXPERT (P)

		D1 vs D2			D1 vs P			D2 vs P		
Number of cases		24			40			24		
		1	0		1	0		1	0	
Function areas										
	1	102	13	118	140	57	197	108	36	144
	0	42	128	170	78	205	283	31	113	144
		144	144	288	218	262	480	139	149	288
Tests										
	1	329	128	457	571	190	761	420	148	568
	0	239	2424	2663	723	3716	4439	396	2156	2552
		568	2552	3120	1294	3906	5200	816	2304	3120
Diagnoses										
	1	10	2	12	10	10	20	7	5	12
	0	2	10	12	2	18	20	1	11	12
		12	12	24	12	28	40	8	16	24
Treatment										
	1	43	12	55	76	13	89	50	6	56
	0	13	128	141	41	178	219	30	110	140
		56	140	196	117	191	308	80	116	196

Note. 1 = a positive decision, i.e. a particular function area (or test or diagnosis or treatment) does apply; 0 = a negative decision, i.e. a particular function area (or test or diagnosis or treatment) does not apply.

In order to understand the data of Table 4.1, both the total number of cases and the total number of decisions involved in the comparisons must be taken into account. In the case of D1 versus D2, for example 24 cases were compared with respect to 12 function areas, which produced a total number of 288 decisions. The diagnosticians were found to agree with each other in 128 (function area not reported as being problematic) + 102 (function area reported as being problematic) = 230 decisions. This is an overall proportion of 230/288 = .80 agreement. This proportion has to be corrected for chance, that is for the agreement that might be expected given the observed marginal frequencies; in the example chance agreement equals (144/288) * (118/288) + (144/288) * (170/288) = .50. Now Cohen's kappa is computed as the amount of agreement over and above the agreement by chance alone: (.80 – .50) / (1 – .50) = .60. For D1 versus D2 the specific agreement

on the assessment tests turns out to be 2*329 / (2*329+128+239) = .64. For treatment recommendation, the total number of decisions was reduced by the fact that comparison was only possible for the diagnosis 'dyslexia'. For D1 versus D2, only 14 cases could be compared with respect to the categories of treatment recommendation.

The descriptive statistics for the various comparisons are summarised in Table 4.2.

Table 4.2 The descriptive statistics of the three comparisons D1 vs D2, D1 vs P and D2 vs P

	Comparison		
Outputs	D1 vs D2	D1 vs P	D2 vs P
Problematic function areas			
overall proportion of agreement	.80	.72	.77
Cohen's kappa	.60	.43	.54
Assessment instruments			
specific agreement measure	.64	.56	.61
Diagnoses			
overall proportion of agreement	.83	.70	.75
Cohen's kappa	.68	.40	.50
Treatment			
overall proportion of agreement	.87	.82	.82
Cohen's kappa	.68	.61	.61

In the comparisons regarding the problematic function areas, the diagnoses, and treatment recommendations, the level of agreement was found to be generally fair to good (Landis & Koch, 1977). The agreement between human diagnosticians and the computer program when D1 versus P and D2 versus P were compared proved to be somewhat lower than the diagnosticians were compared with themselves (D1 versus D2). Nevertheless, the level of agreement was still found to be fair to good.

The difference between the kappas for comparison D1 versus D2 and comparison D2 versus P was not found to be significant. For the problematic function areas, $\chi^2 = .41$ ($df = 1, p > .05$); for the diagnosis, $\chi^2 = .67$ ($df = 1, p > .05$); and for the treatment recommendations $\chi^2 = .62$ ($df = 1, p > .05$). We can conclude that DYSLEXPERT performs at the same level as human experts with regard to these decisions. There is no statistical testing procedure available for the measure of specific agreement calculated for the selection of assessment tests. We can therefore only observe that 55% of the tests selected by one examiner were also selected

by the other examiner regardless of whether it was a human diagnostician or the program DYSLEXPERT.

The agreement measures presented in Table 4.2 are based on the total number of decisions for 24 or 40 cases. The degree of agreement will vary for the individual cases, however. The distributions of the kappas in the D1 versus D2 comparison and in the D2 versus P comparison for the problematic function areas were found to have a great deal of overlap: 21 values occurred between .31 to .83. For the comparison D1 versus D2 one value fell above this range. For the D2 versus P comparison, two values fell below this range. The conclusion based on the chi-square test is corroborated by comparing the means of the kappa values in each comparison, .59 for the D1 versus D2 comparison and .50 for the D2 vs P comparison, which are not significantly different (t-test for paired samples). A similar picture emerges for the treatment recommendations. Individual kappa values are slightly higher in the D1 versus D2 comparison with four values being 1.0. The remaining values varied between .30 and .81, with a mean of .68. In the D2 versus P comparison all of the values fell between .26 and .84, with a mean of .61. Again, these mean values are not significantly different (t-test for paired samples).

The variability of the decisions with respect to the diagnosis is outlined in Table 4.3.

Table 4.3 Results of the comparison for 24 cases of diagnosticians (D1 and D2) and DYSLEXPERT

D1	D2	DYSLEXPERT	Frequency
+	+	+	5
–	–	–	10
+	+	–	5
+	–	+	1
–	+	+	2
+	–	–	1

Note. + = diagnosis 'dyslexia', – = diagnosis 'non dyslexia'.

In 15/24 = 62% of the cases, the first and second analyses by the diagnosticians were in total agreement with the analysis by DYSLEXPERT. This was found to be more often the case for a negative conclusion (the diagnosis 'non dyslexia' in 10 cases) than for a positive conclusion (the diagnosis 'dyslexia' in 5 cases). In 5 cases DYSLEXPERT was found to disagree with the matching diagnoses from the diagnosticians, and in 3 cases the program was found to agree with one diagnostician (D1 or D2) on the diagnosis 'dyslexia'.

Any systematic relation between the kappa values for a particular case and the individual characteristics of that case or the individual diagnostician was not

found. It is conceivable that certain cases may be more difficult to analyse than others and thus produce generally lower agreement values, but this did not appear to be the case.

Finally, the effects of potentially confounding factors such as case recency and same versus different judges were examined. No significant relationship between the recency of the cases and the kappa values in the various decision areas was observed. Similarly, the degree of agreement in cases where D1 and D2 were one and the same person did not prove to be different from the level of agreement for different human judges.

4.5 Conclusions and discussion

The results of the present study indicate that the competence of DYSLEXPERT is similar to that of experienced diagnosticians or at least the expertise of those who participated in this study. With respect to the identification of the problematic function areas and the treatment recommendations, the performance of the program appears to be satisfactory. The same goes for the selection of assessment instruments. With respect to the diagnosis of dyslexia, however, the results appear to be less convincing in view of the fairly substantial standard errors observed for of the kappa measures (.15 and .16). This conclusion immediately raises the question: Can the performance of the program be improved significantly? Before dealing with this question, however, it may be illustrating to compare the performance of DYSLEXPERT to that of similar systems. We are not aware of any system directly comparable to ours, covering the same domain and serving the same purposes. However, in the domain of developmental disorders the problem of diagnosing infantile autism recently has been committed to an expert system called DAI: a knowledge-based system for diagnosing autism (Adarraga & Zaccagnini, 1992). Twenty-seven cases were diagnosed by four experts and the system DAI. The experts identified 11 cases of infantile autism, and DAI recovered 10 of them; of the 16 remaining cases 8 were correctly recovered, 2 were rejected, and 6 were misdiagnosed. The overall hit rate for true positives was 18/27 = .67 or 20/27 = .74, depending on how rejection is judged. These figures are quite similar to the agreement we found between our experts and DYSLEXPERT: .70 (D1 vs P) and .75 (D2 vs P). There are some interesting differences, however, in the evaluation methodology. The study of Adarraga and Zaccagnini was only concerned with just one type of clinical decision, namely diagnoses, whereas we were also interested in related decisions (conclusions from intake interviews, decisions concerning further assessment, and suggestions for treatment). Moreover, in the study of

Adarraga and Zaccagnini the diagnoses of the experts were taken as the definitive criterion for the program. This approach is not without problems. How can we gauge the quality of a program by using a criterion based on human judgement when the latter is known to be unreliable? How wrong can a program be when its performance is compared to a fallible criterion? Adarraga and Zaccagnini seem to recognise this problem, since they mention that the human experts judged three mistakes of the program as being

> "reasonably expectable from any proficient human specialist working under comparable circumstances (i.e. having reports written by others as the only source of information)" (Adarraga & Zaccagnini, 1992, p. 42).

Our solution to this problem is not just a lenient attitude towards the program, but rather the use of an acceptable quantitative bound for evaluating its performance, provided by the level of agreement that humans are capable of reaching.

In order to discern the possible areas for improving DYSLEXPERT, the nature of the cases on which the diagnostic conclusion of the program did not agree with that of the diagnosticians was examined in greater detail. The program's knowledge base, and, in particular, the hierarchically-structured collection of domain concepts and the heuristic rules of inference were checked again. Before the evaluation study started, the set of concepts, their relations and the inference rules had been verified and approved by the original expert. A detailed check of the trace of the program's deviating performance did not reveal any lack of concepts in the knowledge base that might have been responsible for the inadequate processing of the case information.

We next explored the possibility that the diagnoses made by the diagnosticians might be at fault. In one of the cases, possible hereditary background for the reading problems appeared to have been ignored. According to our expert, however, such information is critical to the diagnosis of dyslexia. In other words, the disagreement here cannot be attributed to the functioning of the program.

A more damaging source of disagreement may be the fact that the diagnosticians and the program appeared to proceed in different ways. In four cases, the diagnosticians diagnosed dyslexia while the formally required information with regard to language development, auditory memory, or the association of visual and verbal experiences, was clearly lacking. In the case of missing or incomplete information, DYSLEXPERT proceeds as if there are no problems. In contrast, the diagnosticians appear to use a sort of default logic to create consistency (Reiter, 1980). Even when the pertinent information has not been supplied, the diagnosticians appear to think that certain problems must have been part of the case. The program is more rigid and thus more conservative because it requires formal satisfaction of each of the criteria for dyslexia before it provides such a diagnosis.

This procedural fact is corroborated by the finding that the program had no trouble identifying the cases of non dyslexia. No disagreement between the diagnosticians and DYSLEXPERT was observed for these cases.

Obviously the program can be improved by having it check for critical information and ask for this information when missing. A mechanism for default reasoning (e.g., Witteman, 1992) might also be incorporated into the program. However, the fact that the program is more conservative than humans may be construed as an advantage, particularly when the relevant decisions are made very carefully and explicitly. As Wiggins (1973) has observed: Clinicians may be good at collecting data, but the processing and interpretation should perhaps be left to the computer.

In designing and implementing DYSLEXPERT we did not resort to various techniques of reasoning with uncertainty, for several reasons. First, our primary goal was not to completely supplant human diagnostic expertise but to support it. Moreover, it would have been a much more demanding task to model the process of handling uncertainty as observed in humans, especially since human reasoning is not very well captured by existing formalisms like that of Bayesian decision making. In spite of these difficulties, it would certainly be worthwhile to associate some measure of certainty with the program conclusions; the program performance would certainly get a more 'human' appearance, which in turn might facilitate its acceptance by human diagnosticians. Even as it is, however, DYSLEXPERT has a kind of implicit uncertainty management, which may be used as a starting point for an explicit facility of reasoning with uncertainty. In the current version of the program problematic functioning in a particular domain is established on the basis of information provided by the human diagnostician concerning a large number of specific behaviours, like 'does not discriminate well between left and right' and 'has difficulties in catching and throwing a ball'. These 'symptoms' are usually not 'uncertain', it is only when interpreting the combined evidence provided by a number of symptoms that a qualification of some sort may be required. A simple device would be to make explicit the extent to which an area of psychological functioning is problematic, by noting the proportion of symptoms actually present. This number could be used in the final stage of diagnosing, when the rules for establishing dyslexia are checked. Thus the extent to which a rule is satisfied, when made explicit, could serve as a measure of uncertainty to be associated with the diagnostic conclusions.

When discussing the quality of DYSLEXPERT we should also address the more general issue of how the knowledge-based system was constructed. The performance of the system clearly depends on the validity of the expert knowledge embodied in the program. However, as was mentioned earlier, the reliability and the

validity of the content knowledge is just as relevant for the expert system, as for the human judgements. When an expert system is correct as a program (i.e., has an adequate representation of the domain knowledge and has been flawlessly constructed), faulty conclusions can be attributed to the invalidity of the model of reality on which the program is based, to incomplete knowledge of the domain in question, or to inconsistent knowledge. Similarly, the faulty conclusions drawn by humans can frequently be attributed to an imperfect model of reality. In addition, humans are susceptible to other sources of error; their performance may be flawed "due to fatigue, boredom, memory and attentional limitations, and so on ..." (Einhorn, 1988, p. 66). In these respects, a computer program may actually outperform humans. Recent research shows, indeed, automated clinical judgements to be more accurate than the judgements elicited from clinicians precisely because of the consistency of the automated judgements (Dawes, Faust, & Meehl, 1989; Kleinmuntz, 1990). This means that DYSLEXPERT should, as a program embodying automated clinical reasoning, perform better than human decision-makers. In fact, the requirement that the program performs 'at least at the level of human diagnosticians' is far too lenient and somewhat illogical. At this point, however, we can no longer dismiss the validity of the domain knowledge as an irrelevant issue. It is an inherent characteristic of clinical domain knowledge that the 'correctness' of a diagnosis in general can only be established by checking agreement between judges. However, we can never prove that the decisions on which human diagnosticians agree, are right in any formal sense, as long as we cannot exclude the possibility of systematic error (a wrong model of reality) and random error (inconsistency and unreliability).

In so far DYSLEXPERT uses the same model of reality as humans, however, it is subject to the same kinds of systematic error. It will not show random error, but may continue to make mistakes based on the wrong model of reality or inconsistencies in the knowledge base – just as humans. We are forced to evaluate the decisions of the program against those of humans, moreover, which means that such 'human' error cannot be controlled for in the evaluation of the program. We can show DYSLEXPERT to be at least as good as humans but we cannot show it to be substantially better (Van den Bercken & Blonk, 1994). For this reason, a system such as DYSLEXPERT should be treated primarily as an aid to human decision-making.

Chapter 5
Summary and discussion

In this final chapter, the goal of the project, the development of the expert system, the product, and the results of the evaluation study will be summarised. In connection with these remarks, recommendations for further research and development will be made.

5.1 Brief review of the results

The general goal of the project was to explore the characteristic kinds of knowledge and problem-solving processes used by an expert in the psychodiagnostic field. The creation of an expert system mirroring such knowledge and processes was seen as instrumental to that goal.

In developing such a system we roughly followed the phases described by Buchanan et al. (1983): identification, conceptualisation, formalisation, implementation and evaluation phases.

In the identification phase, we made an inventory of the problems confronted in the diagnosis of reading and spelling problems. The characteristics of the domain and the expert were outlined using the questions proposed by Prerau (1985, 1989). The diagnostic task appeared to contain several subtasks and could be solved using heuristics. In the identification phase, we also addressed the validity and reliability of the expertise of a well-known expert.

In the conceptualisation phase, knowledge was extracted from observations, interviews, examination of a handbook written by the expert, and protocol analyses of intake interviews. The selection of elicitation methods was done by weighing the validity of the method and the efficiency of the method (Neale, 1988). We strove for reliability by documenting every decision in some detail and thereby facilitating replication. In pilot studies, we worked on the formulation of clear and unambiguous categories for the analysis of protocols and the development of a reliable research method (Schellings, 1992; Van Gaal, 1992). We identified 11 functional subdomains as particularly relevant for the diagnosis of reading and spelling problems (see Appendix E). In addition, four main tasks were identified as particularly important in diagnostic reasoning: delimitation of the problem areas, establishment of a diagnosis, individualisation of the problem, and coping with unexpected and/or inconsistent information. We mainly worked bottom-up

but used the KADS library of interpretation models to identify the relevant inference structures in the diagnostic process.

In the formalisation phase, the knowledge was structured following examples from the KADS-library. The analysis tasks from the KADS library of interpretation models – heuristic classification and systematic diagnosis – proved to be particularly useful in the creation of inference structures. Nevertheless, the concrete activities could not be supplied by KADS, and we had to develop our own methods of knowledge elicitation and structuring. The knowledge sources *'abstract'* and *'match'* were apparent in the diagnostic tasks along with the meta-classes *'case description'*, *'diagnosis'* and *'system model'*.

During the implementation phase, the computer program was pragmatically developed by matching the possibilities of the programming language and the demands of the diagnostic task. The domain knowledge was captured in frames and rules; the inference structures and tasks were programmed in procedural terms.

The formal evaluation was conducted by comparing the performance of human diagnosticians with that of the program. The inter-agreement of the diagnosticians was used as a baseline. In general, the performance of the computer proved to be comparable to the performance of the diagnosticians; the program appeared to be somewhat more conservative in the diagnosis of dyslexia than the diagnosticians themselves. This formal evaluation is important for the establishment of the external validity of the program. The diagnosis of reading and spelling problems was modelled in keeping with the expertise of an experienced diagnostician but structured from our point of view. We did not strive for internal validity and did not compare the inferences or reasoning steps found in the program with those followed by the expert therefore.

5.2 Characteristics of diagnostic expert knowledge and reasoning

If we look back at our goal, several things appear to have become clear with respect to the domain knowledge and reasoning. In structuring the domain knowledge of the expert, we identified the diagnostically relevant knowledge as that which is minimally necessary to solve diagnostic problems. This knowledge consists of hierarchical structures of terms that can then be matched to parts of rules. According to Sperber and Wilson (1986), selection of relevant knowledge is central to human information processing. In the artificial intelligence literature (e.g., Chandrasekaran, 1986; Clancey, 1985; Schreiber, 1992), it is often claimed that the domain knowledge could be independent of the problem-solving task. In this project, we have observed that the expert used only those aspects that he viewed

as relevant to the diagnosis of dyslexia, and the particular terms seemed to become relevant by having significant values for certain attributes.

Expert problem-solving is based on heuristic matching principles, which are efficient as a short-cut, replacing earlier hypothetico-deductive inferences to connect data to the more theoretical aspects of a model. We have seen this kind of problem-solving in the diagnostic sub-tasks: problem delimitation, establishment of the diagnosis, and the formulation of a treatment plan.

The fourth task in the diagnostic process of our expert was found to be coping with unexpected or inconsistent information. The fourth task starts as soon as the diagnostician feels that a case cannot be subsumed under his domain knowledge as currently structured. The diagnostician must then decide how to proceed: either look for additional information that might resolve the discrepancy or change the existing knowledge structure.

In the first case, the diagnostician appears to resort to more systematic reasoning. Apparent hypotheses, theoretical foundations, and the usual heuristics are discussed. So-called 'auxiliary hypotheses' may be investigated to provide intermediate solutions that nevertheless remain within the current explanatory model or diagnosis. For example, a discrepancy criterion for dyslexia requires verbal abilities to be significantly lower than performance abilities. When this discrepancy does not appear to be met, and every other criterion for dyslexia is satisfied, the clinician tries to find an explanation for this absence. One auxiliary hypothesis might be a general weakness on tasks with a time-limit. As all standard performance tasks happen to be tasks with a time-limit, this weakness will manifest itself as a low performance score. If such a weakness cannot be established, the diagnosis of dyslexia will have to be rejected. In the second case of coping with inconsistent information, the current knowledge structure is changed. This is called learning as a result of failure (Kolodner, 1984; Kolodner & Simpson, 1986) or more general sustained learning (Aamodt, 1990). The expert said in several interviews that by looking at a child, his theoretical ideas about learning problems were often more sharpened or extended.

In the evaluation study described in Chapter 4, we also identified a strategy employed by diagnosticians to cope with information that is either not available, or not precisely known; diagnosticians simply supply this information by means of a kind of default reasoning. Reiter (1980) sees default reasoning as follows:

> "In the absence of any information to the contrary, assume..." (p. 81).

Default reasoning is an effective way of coping with the real world as it only requires a reaction when something happens out of the ordinary (i.e. out of your world view). For instance, when you take the bus to work every day, you assume

that a bus will appear within every quarter of an hour. If the bus doesn't come, you may still wait for a long time in the basis of this assumption. This default reasoning strategy found to be employed by diagnosticians, was to make unavailable information consistent with available information. This strategy can create cognitive biases and thus be very dangerous.

The reasoning of the expert was also found to be based on qualitative considerations and not probabilities. His decisions are weighted using qualitative arguments. In addition, arguments that are not clear or not available are not admitted by the expert and thus not included in the present system.

5.3 DYSLEXPERT in perspective

Several advantages of an expert system in the area of psychodiagnostics can be distinguished. To start with, the reliability of the system is evident and systematisation of the diagnostic process can be obtained. The program activates all of the relevant concepts and systematically examines each activated concept without the limitations on working memory or long-term memory encountered by humans. By following the program, moreover, the diagnosticians conclusions will be clearly based on facts. Furthermore, diagnosticians can use the various concepts, tests, observations, treatment ideas, and diagnostic criteria contained in DYSLEXPERT to supplement their own knowledge base.

Although DYSLEXPERT performs at the same level as diagnosticians, the value of the expert system in clinical practice, however, has still to be demonstrated. An inquiry at the 1994 Dyslexia Congress showed 84 % of the 251 respondents (teachers, developmental psychologists, and special educators) to be interested in the use of expert knowledge.

Nevertheless, at the moment, DYSLEXPERT has its limitations for application to clinical practice. From a technical perspective, the user-interface is not very user-friendly; comprehensive explanatory facilities and an up-dating mechanism are missing. These aspects should be provided to the intended users.

From the perspective of reading and spelling problems, DYSLEXPERT is limited because we mainly relied on the knowledge of a single expert. Not all professionals agree with the ideas of our expert, and criteria for determining the validity of his decisions simply do not exist. From a more general application perspective, an increased number of instruments and additional ways of reasoning should be admitted.

From the perspective of diagnostic practice, the area covered by DYSLEXPERT is very limited. Only the hypothesis of dyslexia will be examined systematically by

comparison of the activated facts and criteria for dyslexia. If we look at current diagnostic practice, the question is: what is the problem and what may the cause of the problem be? Hypotheses are formulated and tested along a number of intermediate steps, and DYSLEXPERT can be used to test the hypothesis of dyslexia. The evaluation of evidence for several other diagnoses falls outside the program; it only concludes whether there is enough evidence for the diagnosis of dyslexia or not. Nevertheless, if knowledge can be extracted about the other possible causes of reading and spelling problems or more general learning problems, the hierarchical structures of DYSLEXPERT provide the basis for a program that includes more hypotheses. Criteria will have to be set up for the evaluation of the other hypotheses, of course, and the program extended to decide between competing hypotheses and alternative treatment recommendations.

Another item for further development is the domain knowledge base and the criteria associated with an expanded range of diagnoses. At present, a great deal of knowledge about learning problems is accumulated during the diagnostic process while only those aspects relevant to the diagnosis of dyslexia are being evaluated in detail. Given the availability of such an extensive knowledge base, the addition of different diagnoses and different treatment cues would increase the power of the program greatly.

As mentioned in the preceding section, one of the most striking features of the expert's thinking was his handling of unexpected or inconsistent information. As we noted, the expert followed two kinds of strategies to solve the problem: change of the existing knowledge structures or reasoning-based search for additional information. These strategies were as yet not implemented in DYSLEXPERT. For a further development of DYSLEXPERT, there are several possibilities.

First, the domain knowledge may be continuously adapted by accumulating a data-base of submitted cases permitting case-based reasoning. In case-based reasoning (Kolodner, 1993), already existing cases serve as a sort of model for the solution of new cases. Dependent on the features of a new case, a solution will be given, based on the most similar case. Problem-solvers can agree with this solution, but they can also criticise the solution and provide alternatives, which means that the features of the existing knowledge base will have to be revised.

Second, facilities may be added for dealing with the unexpected or inconsistent information, like reasoning with probabilities (e.g., Bacchus, 1990), default reasoning (Reiter, 1980), and reasoning, using the Truth-Maintenance System (Doyle, 1979). Witteman (1992) has shown a computerised decision support system, for choosing between treatment alternatives, called Depri, to be relevant for dealing with ambivalent information, by using the Truth-Maintenance System of Doyle (1979), and the Certainty Factor Model from Shortliffe and Buchanan (1984).

Additionally, reasoning-based search for additional information can be supported by a decision-support system, as already mentioned before. The system can be based, for instance, on a hypothetico-deductive manner of diagnostic reasoning, to provide alternative hypotheses or suggestions for the formulation of alternative hypotheses (Van Aarle & Van den Bercken, 1992; Westmeyer & Hageböck, 1992).

We want to make a last comment to the performance of DYSLEXPERT relative to the performance of a number of diagnosticians. Further evaluation studies could be conducted into the usefulness of the system for actual diagnostic practice and the sensitivity of the program. For example, the performance of diagnosticians using the program might be compared to the performance of diagnosticians not using the program. The hypothesis is that the group of diagnosticians working with the program, will perform better than the group working without the program. Another evaluation study might include a sensitivity analysis (O'Keefe & O'Leary, 1993). An 'ideal dyslexia client' is first presented to the program and then alternative types of input to see whether the conclusions of the system change. Irregular information can be presented to investigate whether the conclusions remain the same. Information can also be deleted and thereby the minimal amount of information needed for a valid diagnosis be determined (Heckerling, Elstein, Terzian, & Kushner, 1991).

A final conclusion is that there is still a large amount of work to be done before expert knowledge can be used at a regular base for diagnostic problems. In the course of this research we became increasingly aware of all the problems inherent in the description of knowledge. Our research also gave us also increasing respect for the capacity of human reasoning to deal with complex problems.

Summary

DYSLEXPERT: The development and evaluation of an expert system for the diagnosis of reading and spelling problems

The goal of this research was to gain greater insight into the complexity of expert knowledge and the manner in which an expert applies this knowledge in daily practice. Within this framework, an expert system for the diagnosis of reading and spelling problems is developed and evaluated. In Chapter 1, the background to this project is discussed: that is, the domain of reading and spelling problems and the psychodiagnostic process. In addition, a number of formal solutions for problems within the area of psychodiagnostics are discussed. In Chapter 2, the specific knowledge analysis undertaken by an expert in the area of diagnosing reading and spelling problems is discussed. In Chapter 3, the expert system DYSLEXPERT is explained; the knowledge base and procedures involved in this system are described. In Chapter 4, the competence of DYSLEXPERT relative to a group of experienced diagnosticians is described. In Chapter 5, an overview of the process of developing the expert system and the empirical research conducted in the framework of this dissertation is presented. The insights gained during development and evaluation are then reported. In closing, some recommendations for further research and development are presented.

In Chapter 1, a number of topics providing the background to the present project are discussed. To start with, a number of the key concepts are explicated: reading, spelling, and dyslexia. The particular standpoint taken on reading and spelling problems is also made clear. Thereafter, the manner in which the diagnosis of reading and spelling problems proceeds in actual practice is discussed. Particular attention is paid to the formal side of the diagnostic decision-making process with the notions of reasoning and knowledge structures standing central. Formal approaches for the support of diagnostic practice are then discussed. Expert systems are further explained and their application within the social sciences and health care are discussed.

In Chapter 2, the knowledge analysis conducted by an expert in the area of diagnosing reading and spelling problems is described. In order to identify and subsequently structure the knowledge elements and reasoning processes, a number of steps are undertaken and described in the different sections of Chapter 2. The relevant data are attained on the basis of observations and interviews. The data are subsumed within hierarchical knowledge structures for which a number of domain rules are formulated. The reasoning processes are represented via a

number of task structures and, in developing these, use was made of the KADS library (Breuker et al., 1987).

Different types of inferences were identified, and the KADS task models of 'heuristic classification' and 'assessment' appeared to provide a good model of a large portion of the diagnostic process. A total of tasks could be distinguished: delimitation of the problem areas, establishment of a diagnosis, formulation of an individualized treatment plan, and dealing with unexpected or inconsistent information during the diagnostic process. The latter task could not be subsumed under the task model at this point.

In Chapter 3, the program DYSLEXPERT is described. To start with, the program is described from the users perspective; how does the co-operation between diagnostician and DYSLEXPERT during the diagnostic process proceed? The diagnostician first enters the personal data. Problematic behaviour is then entered with the aid of a list of 178 problem behaviours. Information on possibly inherited aspects is also entered by the diagnostician. DYSLEXPERT processes this information and provides the user with a list of problem areas and suggestions for further diagnostic activity: useful tests, observations, and/or possible referral. The diagnostician then conducts the necessary tests and observations and enters the data. DYSLEXPERT combines this new information with the previously entered information and then produces a diagnosis and treatment advice.

A number of implementation details are next reported in Chapter 3. An example of a knowledge frame and the relevant domain rules is then presented. Further details on how the data are processed by the DYSLEXPERT program are also presented.

In Chapter 4, an empirical study in which the computer program DYSLEXPERT is compared to experienced diagnosticians is described. A number of cases stemming from the actual practices of the diagnosticians are used for this purpose. The diagnosticians and DYSLEXPERT go through the cases (again). The results ("output") during the diagnostic process (problem areas, suggestions for further analysis, diagnosis, and treatment advice) are noted and compared to each other. Comparisons are also made between the diagnosticians themselves and between the computer system and the diagnosticians. These comparisons clearly show the diagnostic competence of the system to not be inferior to the competence of the diagnosticians. Differences could be traced back to an element of unreliability among the diagnosticians themselves and the restrictions placed on the DYSLEXPERT program.

In Chapter 5, a short summary of the process of developing the expert system DYSLEXPERT is presented. Thereafter, a number of the characteristic features of expert knowledge and reasoning in the domain of diagnosis are discussed. The

possibilities relevant to the fourth task that was identified are also discussed: namely, how to deal with unexpected or inconsistent information during the diagnostic process. Finally, the utility of deploying an expert system such as DYSLEXPERT for the diagnosis of reading and spelling problems in actual practice is discussed. Certain modifications will have to occur in the user interface, however; the knowledge of a single expert should be supplemented with the information attained using other instruments and other reasoning strategies; and the domain of possible diagnosis should be expanded in order to meet the demands of actual practice. Finally, additional facilities should be developed to keep the program up-to-date and to deal with uncertain information.

Samenvatting
DYSLEXPERT: de ontwikkeling en evaluatie van een expert systeem voor de diagnose van lees- en spellingproblemen

Het doel van het proefschrift is meer inzicht te verkrijgen in de gecompliceerdheid van expertkennis en de manier waarop een expert de kennis toepast in de dagelijkse praktijk. In dit kader is een expert systeem ontwikkeld en geëvalueerd voor de diagnostiek van lees- en spellingproblemen. In hoofdstuk 1 wordt de achtergrond van dit project besproken: het domein van lees- en spellingproblemen en het psychodiagnostische proces. Voorts worden een aantal formele oplossingen besproken voor problemen binnen de psychodiagnostiek. In hoofdstuk 2 wordt de kennisanalyse besproken die is uitgevoerd bij een expert op het gebied van de diagnostiek van lees- en spellingproblemen. In hoofdstuk 3 wordt het expert systeem DYSLEXPERT toegelicht; de kennisbasis en de procedures worden beschreven. In hoofdstuk 4 wordt beschreven hoe de competentie van DYSLEXPERT zich verhoudt in vergelijking tot een groep ervaren diagnosten. In hoofdstuk 5 wordt een overzicht gegeven van het ontwikkelingsproces en het empirische onderzoek, uitgevoerd in het kader van dit proefschrift. De inzichten, verkregen tijdens de ontwikkeling en evaluatie, worden gerapporteerd. Tenslotte worden aanbevelingen gegeven voor verdere evaluatie en ontwikkeling.

In hoofdstuk 1 wordt een aantal onderwerpen besproken die een achtergrond bieden voor het project. Allereerst worden een aantal inhoudelijke concepten nader toegelicht: lezen, spellen, en dyslexie. Duidelijk wordt gemaakt vanuit welk standpunt naar lees- en spellingproblemen wordt gekeken. Vervolgens wordt besproken hoe de diagnostiek van lees- en spellingproblemen verloopt in de praktijk. Aandacht wordt vervolgens geschonken aan de formele kant van diagnostische besluitvorming. Hierbij staan allereerst de begrippen redeneren en kennisstructuren centraal. Vervolgens worden formele benaderingen besproken waardoor de diagnostische praktijk ondersteund kan worden. Expert systemen worden verder toegelicht en toepassingen binnen de sociale wetenschappen en de gezondheidszorg worden besproken.

In hoofdstuk 2 wordt de kennisanalyse beschreven die is uitgevoerd bij een expert op het gebied van lees- en spellingproblemen. Om de kenniselementen en redeneerprocessen te verkrijgen en te structureren zijn een aantal stappen ondernomen, beschreven in verschillende paragrafen. Data zijn verkregen middels observaties en interviews. Deze data zijn in hiërarchische kennisstructuren ondergebracht waarbij een aantal domeinregels zijn geformuleerd. De redeneer-

processen zijn middels taakstructuren weergegeven. Hierbij is gebruik gemaakt van de KADS-bibliotheek (Breuker et al., 1987).

Er zijn verschillende typen inferenties geïdentificeerd waarbij de KADS-taakmodellen 'heuristische classificatie' en 'assessment' goede modellen bleken voor een groot deel van het diagnostisch proces. Er zijn in totaal vier taken onderscheiden: probleemafbakening, diagnosestelling, opstellen van een geïndividualiseerd behandelplan en het omgaan met onverwachte of inconsistente informatie gedurende het diagnostische proces. De laatste taak kon niet goed ondergebracht worden in een tot dusverre bekend taakmodel.

In hoofdstuk 3 wordt het programma DYSLEXPERT beschreven. Allereerst wordt het beschreven vanuit het gebruikersperspectief; hoe verloopt de samenwerking tussen diagnost en DYSLEXPERT gedurende het diagnostisch proces. De diagnost voert allereerst persoonsgegevens in. Vervolgens voert de diagnost problematisch gedrag in met behulp van een lijst van 178 probleemgedragingen. Ook voert hij gegevens in over mogelijk erfelijke aspecten. DYSLEXPERT verwerkt de informatie en geeft een lijst van probleemgebieden aan de gebruiker en suggesties voor vervolgacties: zinvolle tests, observaties en/of een mogelijke verdere verwijzing. De diagnost voert het onderzoek met behulp van tests en observaties uit. Vervolgens voert de diagnost deze gegevens in. DYSLEXPERT combineert de nieuwe informatie met de reeds bestaande informatie en komt tot een diagnose en behandelingsadvies. Tot slot staat in hoofdstuk 3 nog een aantal implementatiedetails vermeld. Een voorbeeld van een frame en van domeinregels worden getoond. Ook worden nadere details aangegeven over hoe de gegevens verwerkt worden in het programma DYSLEXPERT.

In hoofdstuk 4 wordt een empirische studie beschreven waarin het computerprogramma DYSLEXPERT wordt vergeleken met ervaren diagnosten. Hiervoor zijn een aantal casussen gebruikt die uit de eigen praktijk van de diagnosten kwamen. De diagnosten en DYSLEXPERT hebben deze casussen (opnieuw) doorlopen. De resultaten ('outputs') tijdens het diagnostisch proces (probleemgebieden, suggesties voor verder onderzoek, de diagnose en het behandelingsadvies) zijn genoteerd en vergeleken met elkaar. Er is een vergelijking gemaakt tussen de diagnosten onderling en tussen de diagnosten en het computersysteem. Hieruit bleek duidelijk dat de competentie van het systeem niet onderdoet voor de competentie van de diagnosten. Verschillen zijn terug te voeren op een stuk onbetrouwbaarheid van de diagnosten zelf en de restricties die DYSLEXPERT zijn opgelegd.

In hoofdstuk 5 wordt een korte samenvatting gegeven van het ontwikkelingsproces van het expert systeem DYSLEXPERT. Vervolgens wordt een aantal karakteristieke kenmerken van diagnostische expertkennis en redeneren besproken.

Mogelijkheden worden besproken om om te gaan met de vierde geïdentificeerde taak: het omgaan met onverwachte of inconsistente informatie gedurende het diagnostische proces. Als laatste wordt besproken dat DYSLEXPERT, als een voorbeeld van een expert systeem bij de diagnostiek van lees- en spellingsproblemen, zinvol in de klinische praktijk kan worden ingezet. Er zullen echter modificaties moeten plaatsvinden aan het gebruikers-interface; de kennis van één expert zal aangevuld moeten worden met andere instrumenten en redeneerstrategieën en het domein van mogelijke diagnosen zal uitgebreid moeten worden om toe te komen aan de eisen die er gesteld worden vanuit de praktijk. Verder zullen een aantal faciliteiten beschikbaar moeten komen om het programma up-to-date te houden en te laten redeneren met onzekere kennis.

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Appendix A - An example of a report and a treatment plan to the parents of a child with reading problems (from the files of the O.P.M -Nijmegen)

Verslag van het psychologisch en orthodidactisch onderzoek van X

Persoonsgegevens

naam	X
onderzoeksleeftijd	8,1 jaar
schoolverloop	groep 1-2-3-3

Reden van onderzoek

Ondanks doubleren van de eerste klas ondervindt X nog veel problemen met lezen en schrijven
Het onderzoek wordt aangevraagd om na te gaan wat de oorzaak van de problemen van X kan zijn en wat er aan gedaan kan worden

Aanvullende informatie

X is het jongste kind in het gezin , hij heeft twee zusjes van 9 en 10 jaar oud
Ook X 's vader heeft vanaf het begin van de lagere school last gehad van lees-/taalproblemen
Van de ontwikkeling van X valt het volgende te vermelden Zwangerschap en bevalling zijn normaal verlopen De motorische ontwikkeling was eveneens normaal en ook de taalontwikkeling was op zich goed Alleen viel op dat X vrij lang "krom" bleef praten en woorden verbasterde ("lullie" i p v "jullie")
X kon altijd goed spelen, hij speelde graag alleen of met zijn zusjes Bij voorkeur speelt hij buiten
Op de kleuterschool viel het de ouders op dat hij nogal speels was en de ouders vroegen zich af of hij niet nog een extra jaar kleuterschool nodig had
Er werd geadviseerd hem toch maar naar de eerste klas te doen In deze klas is X psychologisch getest op verzoek van ouders en school Uit dit onderzoek kwam naar voren dat X over gemiddelde mogelijkheden beschikt, zijn praktische aanleg is beter dan de taalaanleg Auditief geheugen en concentratie zijn zwak evenals de fijne motoriek Er wordt een matige visuele discriminatie en een zwakke auditieve discriminatie geconstateerd De problemen worden voor een deel gezien als gevolg van aanpassingsproblemen aan de nieuwe school
Geadviseerd wordt X rustig, zonder druk, te stimuleren om zijn zelfvertrouwen te vergroten Dat schooljaar is X ook veel ziek en wordt geopereerd, besloten wordt om hem het eerste leerjaar over te laten doen Nu, voor de tweede keer in de eerste klas gaat het eigenlijk niet veel beter X heeft moeite met het lezen, schrijven en onthouden van letters in de juiste volgorde Hij heeft moeite om klanken in woorden te herkennen en kan geen woorden maken van bekende letters Soms schrijft hij letters in spiegelbeeld Hij kan redelijk zelfstandig aan schriftelijke opdrachten werken, maar de concentratie bij mondelinge lessen is zwak Als X een opdracht begrijpt is zijn inzet prima, kan hij iets niet volgen dan is de aandacht minder X vraagt uit zichzelf niet snel om hulp omdat hij bang is dat dan blijkt dat hij fouten maakt Op school krijgt hij nu twee keer per week extra hulp, maar desondanks lijkt het leerproces te stagneren
De ouders en de school vragen zich af wat de oorzaak van X 's problemen kan zijn en wat er aan gedaan kan worden

Vraagstelling voor het onderzoek

1. Wat zijn X.'s intellectuele mogelijkheden? Zijn in de intelligentiestructuur aanknopingspunten voor zijn problemen te vinden?
2. Hoe is de ontwikkeling van functies en voorwaarden?
3. Wat is het didactisch niveau van lezen en spelling?
   Welke problemen zijn daarbij te ontdekken?
4. Hoe is de werkhouding?

Onderzoeksgegevens

Algemene indruk

X. is tijdens het onderzoek aanvankelijk erg gespannen en onzeker. Ook is hij erg gesloten, zegt weinig en wil niet uit de kamer om iets te gaan eten of drinken. Toch werkt hij goed mee; vooral de tweede onderzoeksdag komt hij wat meer los en werkt tot het eind goed gemotiveerd mee. X.'s prestaties zijn over het algemeen nogal wisselend. X. heeft duidelijk meer problemen met de verbale opdrachten dan met de praktische opdrachten. X. kan slecht onder woorden brengen wat hij weet en er moet veel doorgevraagd worden. De practische opdrachten doet hij met duidelijk meer plezier; alleen heeft hij hierbij wat last van een laag werktempo en een zwakke concentratie. Als X. zeker is over een opdracht dan werkt hij rustig en systematisch. Is hij onzeker dan heeft hij de neiging om te blokkeren of om op te geven. Als hij wat meer vertrouwd is met de test en de testsituatie wordt zijn inzet steeds beter.

ad 1. Intelligentieonderzoek

X.'s intellectuele mogelijkheden zijn nader bekeken met de Raven Coloured Progressive Matrices en de WISC-R (bewerking 1986).

De Raven CPM is een test voor nonverbaal logisch redeneren. X. moet hierbij uit verschillende mogelijkheden kiezen welk stuk het best past in een gegeven patroon. Als totaal levert X. op deze test een precies gemiddelde prestatie (50e percentiel).

Hij bekijkt goed alle mogelijkheden, is aanvankelijk weinig duidelijk in zijn antwoorden en presteert erg wisselend: eenvoudige items gaan fout, terwijl moeilijke soms ineens goed gaan.

De WISC-R is een algemene intelligentietest. Binnen deze test onderscheidt men een verbale en een performale schaal. De verbale schaal geeft informatie over de ontwikkeling van de taalvaardigheid, zowel wat betreft de door ervaring en onderwijs aangebrachte kennis als wat betreft het onder woorden brengen van die kennis. De performale schaal geeft informatie over de meer practische intelligentie van een kind, inzicht en vaardigheden, die nodig zijn om bijvoorbeeld mozaïekpatronen na te leggen of legpuzzels te maken.

Als totaal levert X. op deze test een gemiddelde prestatie: totaal IQ = 97. De prestaties op het verbale gedeelte van de test komen (in cijfers) hetzelfde uit als de prestaties op het performale gedeelte: verbaal IQ = 97, performaal IQ = 97.

X. heeft met de verbale opdrachten duidelijk meer moeite dan met de practische opdrachten; door de mogelijkheid die de test biedt tot doorvragen op de verbale onderdelen en doordat bij de practische opdrachten het werktempo duidelijk meetelt in de beoordeling komen de beide schalen in cijfers gelijk uit.

Het intelligentieprofiel is echter erg disharmonisch opgebouwd met scores variërend tussen 4 en 15 (op een schaal van 1–19).

De verschillen worden duidelijk als wij kijken naar de factor analytische structuur van de intelligentie. De verbale begripsfactor komt hoog gemiddeld uit; deze factor wordt gevormd door de vol-

gende onderdelen overeenkomsten (score 10), waarmee het verbaal abstractievermogen gemeten wordt (bijv wat is de overeenkomst tussen boosheid en blijdschap), woordenschat (score 11), waarbij gevraagd wordt de betekenis van woorden uit te leggen en het onderdeel begrijpen (score 15), waarbij gevraagd wordt inzicht in alledaagse sociale situaties onder woorden te brengen Hoewel X moeizaam formuleert en veel doorvragen nodig is kan hij toch voldoende duidelijk maken dat hij iets begrijpt

De tweede factor, de ruimtelijke analytische factor komt gemiddeld uit (10 1/3) Deze factor wordt gevormd door de onderdelen onvolledige tekeningen (score 12), blokpatronen (score 11) en legpuzzels (score 8) Bij onvolledige tekeningen wordt gevraagd aan te geven wat is weggelaten in een tekening, bij het onderdeel blokpatronen gaat het om snel en correct naleggen van mozaiekpatronen, terwijl bij legpuzzels gevraagd wordt een puzzel te maken zonder voorbeeld Het onbreken van het voorbeeld maakt X onzeker en hierdoor komt hij op dit laatste onderdeel tot een relatief zwakke prestatie

De derde factor is de sequentieer- of concentratiefactor Bij deze factor, die wordt gevormd door de onderdelen rekenopgaven (score 8), cijferreeksen (score 5) en substitutie (score 4) gaat het om het snel en efficient opnemen, opslaan en verwerken van vrij willekeurige informatie Op deze factor wordt vooral een beroep gedaan bij het schoolse leren en juist deze factor komt bij X erg laag uit (5 2/3) Bij het onderdeel rekenopgaven wordt gevraagd eenvoudige redactieopgaven uit het hoofd uit te rekenen, bij cijferreeksen moet X een steeds langere reeks cijfers in de juiste en in omgekeerde volgorde nazeggen Geheugen en geheugenstrategieen spelen bij deze onderdelen een rol Bij substitutie wordt nagegaan hoe snel een kind de koppeling leert tussen een cijfer en een symbool, visueel geheugen en associatietief leervermogen spelen hierbij een rol

Uit het intelligentieonderzoek komt naar voren dat X over voldoende mogelijkheden beschikt om het gewone lager onderwijs te kunnen volgen Verbaal begrip en ruimtelijke-analytisch inzicht zijn zelfs ruim voldoende Het opnemen, opslaan en verwerken van vrij willekeurige informatie is echter zwak

Daar in het onderwijs juist hierop een beroep gedaan wordt zijn in deze zwakke factor in de intelligentiestructuur aanknopingspunten te vinden voor X 's problemen met het schoolse leren

ad 2. Onderzoek van functies en voorwaarden

a Visuele ontwikkeling en visuomotoriek

- visuele waarneming Motor Free Visual Perception Test X levert op deze test een goede prestatie (waarnemingsleeftijd boven 9 jaar),
- visueel onderscheidingsvermogen WISC-R onvolledige tekeningen score 12 (hoog gemiddeld),
- visuomotoriek Developmental Test of Visual-motor Integration Op deze test levert X een normale prestatie, die iets boven zijn leeftijdsniveau ligt (overeenkomstig 8,7 jaar)
- visueel geheugen en visuomotoriek Memory for Design Test Ook op deze test levert X een goede prestatie
- visueel geheugen Bannatyne visuo-spatial memory test Op deze niet genormeerde test wijst X 9 maal de juiste figuur aan, 3 maal een spiegeling, 1 maal een rotatie en 2 maal een fragmentatie Gezien de goede uitslagen op de andere visuele tests lijkt hier vooral de wat zwakkere concentratie een rol gespeeld te hebben

Daar X bij lezen en schrijven veel last van omkeringen heeft is dit aspect van de visuele waarneming bekeken met de Reversal Test van Edfeldt Dit is een test die eind kleuterschool afgenomen wordt om na te gaan of een kind er wel of niet aan toe is om te gaan leren lezen X s prestaties op deze test zijn ruim voldoende

De visuele lees-/taal voorwaarden worden besproken bij het didactisch onderzoek

b Taalontwikkeling en auditieve voorwaarden

X 's verbale mogelijkheden zijn als totaal voldoende ontwikkeld WISC-R verbaal IQ = 97

Toch valt in de expressieve taal op dat X moeilijk onder woorden kan brengen wat hij denkt of weet Hij heeft last van woordvindingsproblemen en de zinnen die hij maakt zijn eenvoudig en vaak niet goed gevormd

Enkele aspecten van de taalontwikkeling zijn nader bekeken met de Taaltest voor Kinderen (TVK) Afgenomen zijn de onderdelen betreffende het fonologisch aspect van de taal (klankniveau) en het morfologisch aspect (woordvormen) X komt tot de volgende prestaties (zie bijlage)

- Auditieve woorddiscriminatie (horen of twee woorden gelijk of verschillend zijn) percentielscore 85
- Auditieve synthese (losse klanken samenvoegen tot een woord) percentielscore 5
- Woordherkenning (een woord herkennen als je er een deel van hoort) percentielscore 8
- Woordvormenbeoordeling (juiste woordvorm herkennen) percentielscore 6
- Woordvormenproductie (juiste woordvormen zeggen) percentielscore 22

Daar bij deze onderdelen ook het auditief geheugen een rol speelt is dit nader bekeken met de volgende onderdelen van de WISC-R en de Leidse Diagnostische Test (LDT)

- WISC-R cijferreeksen nazeggen score 5 (zwak)
- LDT woordenspan (woorden nazeggen) IQ 90
- LDT plaatjes aanwijzen (de plaatjes aanwijzen die horen bij woordenspan) IQ 98
- LDT zinnen nazeggen IQ 76
- LDT verhaaltje vragen IQ 85

Op het gebied van de taalontwikkeling worden problemen geconstateerd op fonologisch en morfologisch niveau Ook het auditief geheugen is zwak

De auditieve lees-/taalvoorwaarden worden verder besproken bij het didactisch onderzoek

ad 3. Didactisch onderzoek

Lees-/taalvoorwaarden

De lees-/taalvoorwaarden zijn onderzocht met de Instapproeven

Visuele discriminatie van letter- en woordvormen

Alle onderdelen worden voldoende beheerst

Auditief structuren van klanken

- Auditieve synthese (losse klanken samenvoegen tot een woord) onvoldoende beheersing bij meer dan één medeklinker voor of achteraan, voldoende bij een medeklinker voor of achteraan
- Auditieve analyse (een woord uiteenleggen in losse klanken) voldoende bij één medeklinker voor of achteraan, onvoldoende bij meerdere medeklinkers voor of achteraan
- Gelijke klanken horen in twee woorden onvoldoende bij de klinkers, voldoende bij de medeklinkers
- Ongelijke klanken horen in twee woorden onvoldoende zowel bij klinkers als bij medeklinkers
- Klankpositie bepalen (aangeven op welke plaats in een woord je de aangegeven klank hoort) voldoende voor woorden met één medeklinker voor- en/of achteraan onvoldoende bij meerdere medeklinkers

De auditieve lees-/taalvoorwaarden worden slechts beheerst voor woordtypen met één medeklinker voor- en/of achteraan

Letterkennis (Instapproeven)

Letters lezen beheersing 90% (voldoende)

Letterdictee beheersing 90% (voldoende)

Problemen worden gezien bij g, ch, ei, v, f, au en veel aarzelingen
De letterkennis is nog niet geautomatiseerd
Lezen
Woorden lezen
- Instapproeven woorden met één medeklinker voor- en/of achteraan worden voldoende beheerst
- Brus Eén Minuut Test X leest 6 woorden goed en 3 fout in één minuut (zeer zwak)
- LPC Eén Minuut Test bij deze test leest X 22 woorden goed en 1 fout niveau halverwege klas 1

Zinnen lezen Instapproeven beheersingsniveau onvoldoende
- AVI leeskaart 1A onvoldoende, zowel wat betreft tijd als aantal fouten (40%) Hoewel X zacht voor zichzelf spelt leest hij vaak iets anders dan er staat

Begrijpend lezen Instapproeven beheersingsniveau is onvoldoende (70%) Begrip van het gelezene is onvoldoende omdat het technisch lezen zeer zwak is
Spelling (Instapproeven)
Woorddictee beheersing 20% (zwak)
Zinnendictee beheersing 42% (onvoldoende)
Zowel lezen en spelling als de auditieve lees-/taalvoorwaarden zijn nog op een aanvankelijk niveau

ad 4. Werkhouding
X heeft aanvankelijk moeite om in een vreemde omgeving tot een voor hem normale werkaanpak te komen Hij is onzeker en wisselend in zijn prestaties Toch kan X , wanneer hij goed weet wat de opdracht is en er zeker van is dat hij het het kan, tot goede prestaties komen met een systematische aanpakken een goede controle Gaat hij echter twijfelen of hij iets kan dan heeft hij de neiging te blokkeren en op te geven Als hij dan toch verder werkt gebeurt dit radend en uitproberend zonder duidelijk systeem Bemoediging of ervaren dat iets wel lukt kan hem weer tot een goede systematische aanpak brengen Wanneer hij zich meer op zijn gemak voelt werkt hij tot het laatst toe goed gemotiveerd mee, ook aan voor hem moeilijke opdrachten Van belang blijkt dan te zijn dat er rekening gehouden wordt met X s wisselende concentratie en zijn zwakke auditieve geheugen omdat hij vooral onzeker wordt als hij de informatie of de opdracht weer even kwijt is
Getracht is met behulp van de Columbusplaten en de CAT na te gaan of er aanknopingspunten voor X s onzekerheid te vinden zijn in zijn persoonlijkheidsontwikkeling Deze verhalentest, waarbij van X gevraagd wordt om verhalen van platen te vertellen geeft weinig informatie Hij beschrijft globaal wat hij op de platen ziet en zegt niet meer te weten De projectieve waarde van de verhalen is derhalve gering en kan beter op een later tijdstip, als X wat ouder is, herhaald worden

Conclusie en advies

Hoewel X over voldoende mogelijkheden beschikt om het gewone onderwijs te kunnen volgen zijn er in de intelligentiestructuur wel aanknopingspunten te vinden voor de problemen die hij ondervindt bij het schoolse leren Terwijl verbaal begrip en ruimtelijk-analytisch inzicht (ruim) voldoende zijn is het opnemen, opslaan en verwerken van vrij willekeurige informatie zwak Bij het schoolse leren wordt juist op deze vaardigheid een beroep gedaan Uit het onderzoek van functies en voorwaarden komt naar voren dat er op visueel gebied geen problemen geconstateerd worden Echter op het gebied van de taalontwikkeling en de auditieve voorwaarden is sprake van een achterstand X heeft moeite om wat hij denkt of weet onder woorden te brengen, hij heeft woordvindingsproblemen en de zinsbouw is zwak De taalontwikkeling vertoont nog zwakke punten op fonologisch en morfologisch ni-

veau, het auditief geheugen is zwak en de auditieve lees-/taalvoorwaarden worden slechts beheerst op het niveau van woorden met één medeklinker voor- en/of achteraan.
Op didactisch gebied is de letterkennis wel redelijk aanwezig maar nog niet geautomatiseerd. Lezen is nog zwak en wordt matig beheerst op het niveau van woorden met één medeklinker voor- en/of achteraan; X. leest, ondanks spellen, vaak iets anders dan er staat. De spelling is nog op een aanvankelijke niveau, een goede strategie ontbreekt.
Hoewel X. in de loop van het onderzoek steeds beter mee gaat werken blijkt toch steeds dat als hij onzeker is en twijfelt of hij iets kan, hij de neiging heeft te blokkeren en op te geven of over te gaan op een niet systematische, radende werkstrategie. Bemoediging en succeservaring kunnen hem hier wel overheen helpen, waardoor hij tot het laatst toe goed blijft meewerken.
Gezien de problemen, vooral kwalitatief, die X. ondervindt bij verbale opdrachten, de achterstand in taalontwikkeling en op het gebied van de auditieve lees-/taalvoorwaarden met daarnaast een goede visueel-ruimtelijke ontwikkeling, gecombineerd met een achterstand op het gebied van lezen en spelling kan men stellen dat er bij X. sprake is van dyslexie.
Geadviseerd wordt voor hem een individuele orthodidactische behandeling van de lees-/taalproblemen. Hierbij moet gestart worden op het niveau dat hij nog juist wel beheerst (zoals in het onderzoek naar voren kwam) om vandaaruit stapgewijs het lees-/taalproces op te bouwen.
Het verdient ook aanbeveling om als ondersteuning aandacht te besteden aan de taalontwikkeling. Een precieser handelingsplan kan in overleg opgesteld worden.
Met de ouders en de school zal overlegd worden hoe een aanpak van de problemen van X. te realiseren valt.

Orthodidactisch behandelingsplan voor X.

Pedagogische en didactische aanpak

- Korte, wisselende opdrachten geven
- Stap voor stap werken, aangepast aan zijn niveau
- Regelmatig herhalen van oefeningen rondom bepaalde moeilijkheden
- Noteren welke moeilijkheden in zijn werk blijven terugkomen (regelmatig fouten-analyses maken) en deze blijven oefenen
- Het werk door hem zelf laten nakijken
- Hem motiveren door hem directe informatie te geven over zijn resultaten
- Positieve verwachtingen uitspreken
- Bepaalde doelen stellen die niet te hoog en niet te laag zijn; hem ook zelf bepaalde doelen laten stellen, bijvoorbeeld hoeveel denk je dat je er goed leest/schrijft?
- Goede resultaten toeschrijven aan zijn eigen inzet of bekwaamheid
- X. heeft een consequente, structuurvolle benadering nodig; hij moet duidelijk weten wat er van hem verwacht wordt
- De volgende opbouw gebruiken:
  - voorbereidende oefeningen, voorwaarden;
  - lezen van letters, woorden, zinnen;
  - schrijven van letters, woorden en zinnen.
- De principes van zelf-instructie en verbaliseren zijn erg belangrijk in de orthodidactiek. Het verbaliseren is het onder woorden brengen van een handeling of oplossingsmethode. Dit is een onderdeel van een zelfinstructieprocedure, waarin een kind geleerd wordt op een ordelijke wijze de zaken waarmee hij bezig is op een rijtje te zetten.

A. Taalgebruik

Als ondersteuning van het lees-/taalproces kan de expressieve taal geoefend worden.

1. *Woordenschat*
   - woorden noemen bij een bepaald onderwerp of trefwoord
   - tegenstelling aangeven
   - overeenkomst aangeven
   - woorden langer maken
   - synoniemen vinden
   - omschrijving van woorden geven
   - ketting rijgen: maak een nieuw woord met de laatste letter van het vorig woord.
2. *Woordvorming*
   - meervoudsvormen
   - werkwoordsvormen
   - verkleinwoorden.
3. *Zinsbouw*
   - zin maken met bepaalde woorden
   - zinnen afmaken
   - aangeven of een zin goed of fout is
   - een foute zin verbeteren
   - vertellen naar aanleiding van een plaat
   - zin maken naar aanleiding van vragen bij een verhaalplaat
   - zinnen langer of korter maken
   - zin maken met dezelfde betekenis
   - van twee of meer zinnen één zin maken
   - een tegengestelde zin maken
   - verhaal navertellen of samenvatten.

Leermiddelen

- Van de Geest/Swüste: Taalaktiveringsprogramma
- Schaap/Soutberg: Training van de verbaal/expressieve taal.

B. Auditieve training

Daar X. nog problemen heeft met de auditieve voorwaarden is het van veel belang dat deze voorwaarden goed geoefend worden omdat hierop het lees-/taalproces wordt opgebouwd.

1. *Auditief geheugen*
   - nazeggen van woorden en zinnen (reeks van 4 à 5 woorden)
   - vragen over zinnen of een verhaaltje
   - welk woord is anders in twee zinnen?
   - welk woord is weg in een zin of een reeks woorden?
2. *Auditieve analyse*
   - een woord verdelen in lettergrepen
   - een woord verdelen in losse klanken
3. *Auditieve synthese*
   - losse klanken samenvoegen tot een woord
   - lettergrepen samenvoegen tot een woord

4. *Auditieve closure*
   Een woord herkennen als het met weglating van één of meer klinkers of mede-klinkers wordt aangeboden.
5. *Automatiseren van de klank-letterkoppeling, toegespitst op:*
   Aan dit onderdeel zal veel aandacht besteed moeten worden omdat X. veel moeite heeft met het leren van symbolen. Eventueel kan het leerproces ondersteund worden door te werken met kleuren, en met schuurpapieren letters.
   - korte en lange klinkers in een gesloten lettergreep (aa - a; uu - u, etc.)
   - klinkers met gering auditief verschil (eu - ui - u)
   - moeilijke beginmedeklinkers (f-v, s-z)
   - klinkers en medeklinkers met gering visueel verschil (ie - ei, au - ou, b - d, g - ch).

   Kooreman (methode Letterstad) geeft sommige letters een bijnaam, waardoor het auditieve en het visuele aan elkaar verbonden worden. Ook besteedt Kooreman aandacht aan de motorische component bij het koppelen van klank en teken (de richting van de letter wordt met grote armbewegingen in de lucht geschreven). Telekns wanneer het kind een moielijke letter krijgt aangeboden wordt hij (eerst door de leerkracht, later door zichzelf) gedwongen aan het ezelsbruggetje te denken.

Leermiddelen
- T. In den Kleef, Curriculum Schoolrijpheid deel 2A, "Auditieve Training": opbouw bij klankzuivere woorden: mkm, mmkm-mkmm, mmkmm, mmmkm-mkmmm.
- A. Heijmans, Mijn Taalboek, deel 1.
- Kooreman, Letterstad.

C. Lezen

Bij het lezen moet de volgende strategie worden geleerd: voordat een woord hardop wordt uitgesproken moeten de letters stuk voor stuk, van links naar rechts verklankt worden (eerst hardop, daarna zachtjes).

Om de aandacht op de losse letters te richten is het goed met een lettergat te werken. Er moet begonnen worden met het lezen van éénlettergrepige klankzuivere woorden. Opbouw bij klankzuivere woorden:

m-k-m
m-m-k-m - m-k-m-m
m-m-k-m-m
m-m-m-k-m - m-k-m-m-m enzovoort.

De volgende oefeningen kunnen worden gedaan:

1. *Woorden nauwkeurig leren lezen*
   - woordrijen lezen; het is goed een speciaal schrift (ruitjes-schrift met hokjes van 1 x 1 cm) aan te leggen waarin iedere keer een nieuwe rij woorden wordt geschreven; in ieder hokje wordt 1 letter geschreven (n.b.: tweeklank in 1 hokje).
     Mogelijke aanpak:
     - woorden hardop spellen, hardop tot synthese komen (r - oo - s roos)
     - woorden hardop sneller spellen, hardop tot synthese komen (r.oo.s roos)
     - zonder spellen het hele woord hardop zeggen; het lettergat kan dan vervangen worden door een woordgat.
   - wisselrijtjes lezen; wisselrijtjes bestaan uit enkele woorden waarin de eerste, middelste of laatste letter verandert

- telkens een langer woord lezen, steeds een letter erbij lezen

Het woorden lezen kan ook geoefend worden met de cassetterecorder door het principe van de dubbele input-methode te gebruiken

De verschillende stappen bij het woorden lezen worden op de band uitgesproken zodat het kind tegelijkertijd bij het spellen of lezen van het woord (naar gelang de stap waar hij aan toe is) te horen krijgt hoe het woord gespeld of gelezen moet worden Er is zo een directe auditieve feedback mogelijk

2 *Woorden snel leren lezen*

Wanneer het nauwkeurig lezen van bepaalde woorden voldoende is geoefend, kan begonnen worden met het opvoeren van het leestempo

Hierbij kan gebruik gemaakt worden van de eerder genoemde reeds geoefende woordrijen en van flitskaartjes Deze woordkaartjes dienen om het snel overzien van een woord te oefenen Een woord wordt even getoond, dan bedekt of uitgeveegd

Het is vaak motiverend voor kinderen de resultaten in een grafiek weer te geven Genoteerd wordt zowel het aantal goed gelezen woorden als de tijd, zodat de vorderingen zichtbaar zijn

3 *Zinnen lezen*

Zinnen lezen met woorden die van tevoren apart gelezen zijn eerst zachtjes de woorden lezen, dan de hele zin lezen in een keer

4 *Teksten lezen uit een leesboek op zijn niveau*

- Het is erg motiverend om een tekst samen te lezen Om de beurt leest ieder een zin en de ander leest zachtjes mee Als er een fout gemaakt is, leest de ander niet door maar wacht de zin moet opnieuw gelezen worden
- Ook om het leestempo te bevorderen kan gebruik worden gemaakt van het principe van de 'kijk- en luistermethode Dit moet gebeuren in het verlengde van het zinnen lezen door bijvoorbeeld zelf teksten van het goede niveau op cassette in te spreken Het is belangrijk dat X zelf meeleest en dit moet steeds goed gecontroleerd worden Het geluid kan steeds zachter gedraaid worden zodat hij steeds meer alleen gaat lezen

Elk woord ondergaat dus in principe 4 à 5 behandelingen

- in de auditieve training bij analyse- en synthese oefeningen
- in het spellend lezen zonder tijdsdruk synthetiserend
- in het herkennend lezen flitskaarten
- in het zinnen lezen eerst zachtjes voor zichzelf dan hardop
- in het teksten lezen

De laatste vier behandelingsfasen kunnen via het principe van de dubbele input methode ondersteund worden met ingesproken cassettes

In de eerste fase kunnen drie subfasen onderkend worden

- duidelijk analyseren in losse klanken r - oo - s
- vervloeiende klanken r oo s
- uitspraak als een geheel

Leermiddelen

- A Heijmans, Mijn Taalboek deel 1 en 2
- Van Lierop, Structuuroefeningen
- A Bulthuis, Taal is niet zo moeilijk
- Woorden uit Curriculum Schoolrijpheid deel 2A
- Caesar, Veilig Leren Lezen, Structuurrijen
- Stap voor Stap

- Leesboekjes van Kooreman Mik en Mak, Jouk

D. Spelling

Er worden alleen woorden geschreven die van tevoren al gelezen zijn Ook hier wordt begonnen met klankzuivere woorden

Voor het schrijven wordt de volgende strategie gebruikt

- gedicteerde woorden of zinnen correct nazeggen,
- woorden vooraf spellen door het noemen van de letters, zoals je ze hoort,
- meespreken tijdens het schrijven door het zachtjes zeggen van iedere letter,
- woorden nalezen en controleren en eventueel corrigeren

De volgende oefeningen zijn zinvol

- uit het hoofd overschrijven van woorden en zinnen (zonder terug te kijken)
- woordspelletjes woorden bedenken met een bepaalde klinker of medeklinker en deze opschrijven (Auditieve Training niveau 3 6 en 5 11)
- invuloefeningen invullen van de ontbrekende letter in een woord
- auditief woorddictee van de geoefende woorden
- auditief zinnendictee met woorden die beheerst worden in het woorddictee

Wanneer het schrijven van klankzuivere woorden geen problemen meer oplevert, moeten de spellingsregels systematisch worden aangeleerd

Hierbij kan gebruik gemaakt worden van de vier hoofdregels van A Heijmans uit Mijn Taalboek, deel 2

Als leidraad hiervoor kan het regelschrift' gebruikt worden van T In den Kleef, waarin de spellingsregels stapsgewijs worden aangeboden

Het is de bedoeling dat er samen met X een regelschrift wordt gemaakt waarin alle spellingsregels genoteerd worden en dat hij leert gebruiken bij alles wat hij moet opschrijven Geleidelijk aan kunnen de regels bij steeds moeilijker woorden worden toegepast

Ter ondersteuning van de spellingsregels moet geoefend worden

- woorden op het gehoor in lettergrepen verdelen,
- het horen van de klemtoon in meerlettergrepige woorden,
- de termen lettergreep - klemtoon - toonloze e - klinkers en medeklinkers,
- de begrippen zelfstandig naamwoord - bijvoeglijk naamwoord - werkwoord - lidwoord - enkelvoud en meervoud

Deze termen worden eveneens genoteerd in het regelschrift en geoefend in mondelinge en schriftelijke rubriceeroefeningen

Leermiddelen

- 'Curriculum Schoolrijpheid', deel 2A, "Auditieve Training"
- A Heijmans Mijn Taalboek deel 1 en 2
- A Bulthuis Taal is niet zo moeilijk
- Werkbladen bij klank-synthese methode van Heijmans S B D Den Helder

Excerpt 1

J: the expert
V: father of the client
M: mother of the client
D: the client

.....

J Eh heeft u .... eh bij D. ook wel eens iets eh gemerkt van benoemen van rechts en links?
M Ja daar heeft ie eh nog steeds moeite mee.
J Heeft ie nog steeds moeite mee.
M Ja.
J Dus als hij in de auto zit en hij zegt de weg ...
M Ja.
J ... rechtsaf of linksaf, dan moet u altijd nog vragen welke rechts bedoel je?
M Nou het is meer met met handen geven en de auto eh daar ben ik me daar niet zo bewust van maar .... wel als ie iemand moet feliciteren welke hand is het nou weer, ja die of moet ..
J En en dan dan dan ....
M Dan vraagt ie dat toch nog gauw ....
V Nou, dan weet ie wel wat rechts of links is, maar dan weet ie niet welke hand ie nou moet geven.
M Ja.
J Dus als je tegen hem zegt eh D. weet wel je rechterhand, dan zit ie nog te kijken, van welke is nou mijn rechter hand?
V Nee, dat dacht ik niet.
M Dat weet ie wel.
V Als je zegt de rechter hand, dan geeft hij ook de rechter hand.
J en M Oh ja .....
V Maar je weet soms niet wat .... ja, wat moet ik nou is het nou de rechter of de linker hand die ik moet geven.
J Ja.
V Maar gewoon rechts of links dat eh dat weet ie wel.
M Ja.
J Nu komen we op een punt wat u zelf eh wat u al eerder gezegd heeft, dat ie eh, bij die cijfers wel eens omdraaiingen heeft.
V Ja.
J Daar zit eigenlijk ook in zekere zin rechts of links in he ...
M Hmhe ....
J .... want je moet van links naar rechts lezen, maar je moet eigenlijk van rechts naar links praten, bij cijfers ....
M Hmhe.
J .... en bij grotere cijfers, gelukkig had ie dit nog niet, maar bij grotere cijfers moet je zelfs ..... dan moet je zelfs springen he, van rechts naar links, van links naar rechts, dat is iets waar die nog steeds moeite mee heeft.

M Ja

J Zijn er andere voorbeelden waarin, waaruit dat blijkt dat probleem van rechts en links benoemen, dus zeggen dat rechts is en dat links links is?

M Mmmm niet dat .....

J Bij zijn kleren aantrekken, nooit iets gemerkt?

M Nee dat niet, nee ook niet.

.....

Excerpt 2

J the expert diagnostician
I a collegue
A myself

I Ehm, uit het intelligentie-onderzoek, even wat daaruit naar voren kwam?
J Ja
I Raven, op het 75e percentiel, dus eh boven gemiddeld
WISC-R is best wel een grappig beeld, in de zin dat er eh in verbale intelligentie en performale intelligentie en totale intelligentie lijkt er een heel harmonisch beeld uit te komen
J Ja
I maar als je het profiel ziet dan is dat eh varieert eh varieren de scores tussen de 5 en de 15
J Hmhmm
I Krijg je, kijk je naar de factorstructuur
J Hmhmm
I dan wordt er eigenlijk wel iets duidelijker
J Waar kunnen we daar naar
I Hier
J Oh ja, ha
I Ha, heb ik dat dan ja
J Ja
I Namelijk de verbale begripsfactor 14, ruimtelijke analytische factor 12, de concentratiefactor 8 Dus duidelijk een probleem met het eh opnemen, opslaan en verwerken van vrij willekeurige informatie Waarbij nog opvalt dat met name de auditieve aangeboden informatie moeilijker verwerkt wordt dan eh visueel aangeboden, substitutie is 12 dat is hoog gemiddeld, maar rekenopgaven en cijferreeksen waar allebei het geheugen een rol bij speelt zijn zwak Vooral cijferreeksen met een score van 5 is zeer zwak
J Ja,Nou dat ehm, ja dat is misschien even goed voor de, voor de gedachtenbepaling
J dat de concentratiefactor zwakker is dan de andere twee
J dat kun je bijna uit de hele literatuur over de wisc zelf al afleiden
J want als je de test eh bekijkt, ook in een steekproef normale kinderen, dan scoren die toch doorgaans op die drie subtesten die samen de concentratiefactor vormen het laagst Maar vooral de dyslectische kinderen die zijn altijd met die drie tests het laagst
J Nu is, dan blijft eigenlijk nog over, als je dat weet, hoe is de vorm dus verbale begrip en de ruimtelijke analytische factor en dit beeld wat je hier ziet dat pleit duidelijk tegen dyslexie
Omdat bij dyslexie de ruimtelijke factor eh niet alleen eh beter moet zijn dan de verbale begripsfactor, maar ook aanzienlijk beter ja? Dat eh leer je dus eigenlijk uit de theorie en dat wordt dus hier niet bevestigd dus dat pleit tegen het hele idee van dyslexie Dus, want je hebt nog wel eens dat die eh verbale en die performale schaal niet zo drastisch van elkaar verschillen
J eh dan ga je kijken naar de factoren, maar die moeten dan toch wel heel duidelijk verschillen En deze verschillen dus de verkeerde kant, in ieder geval de andere kant op dan verwacht is He?

I Wat alleen dus toch wel weer het, het auditief geheugen wat duidelijk zwak is Want dat was ook eh een van de redenen waarom hij daar zo laag op uit kwam Dat was bij het hele onderzoek ook kwam naar voren dat hij vaak opdrachten herhaald moesten worden en dergelijke Eh dus, wat is er verder nagegaan De auditieve voorwaarden zijn nagegaan Ook omdat er sprake was om dat duidelijk te beantwoorden Auditieve analyse gaat op zich voldoende Synthese ook wel Toepassing van analyse en synthese geeft problemen bij de langere woorden Dus meerdere medeklinkers voor of achteraan

J Hmhmm

I En met name als er gevraagd wordt een medeklinker weg te laten die midden in het woord staat, dus niet de eerste of de laatste, maar een vooraan, of een eh in het midden

J Hm

I Niet perfect voor zijn leeftijd

I Niet vlekkeloos Ook wat moeizaam

A En wat, wat denk je daar dan bij, als je, als je zo n resultaat ziet?

I Dat hij toch wel eens problemen zou kunnen hebben met lezen en spelling

I Want als dit volledig in orde is, dan verwacht je geen problemen, niet direct problemen met lezen en spelling Want bij een dyslexie is dit over het algemeen wel zwak Nou, bij hem is het niet extreem zwak maar Wat ook kan bij het eind van de opdracht dat het de concentratie is

I Dat die weg is en dat hij het daarom niet goed

J Ja want kijk, meestal na het kwantitatieve aspect haalt hij alle items wel maar de kwaliteit kan, ook al haalt hij bijna op alle items, kan de kwaliteit nog eh betrekkelijk eh gering zijn Wanneer hij te lang eh of teveel moeite heeft om in te prenten en je ziet ook dat hij dus moet, datgene wat hij ingeprent heeft met moeite moet eh vasthouden om dat eh vervolgens goed te kunnen synthetiseren

Ja en dat is ook waar jij op wijst dat eh, dat het soms toch wat moeizaam gaat ja en het moet eigenlijk volkomen snel en vlekkeloos gebeuren

Excerpt 3

J: the expert
I: a collegue
V: the father of the client
M: the mother of the client

.....

I De vraag was in .... indertijd van is hier sprake van dyslexie.....
M Ja.
I H, dat was .... dat komt uit het onderzoek niet helemaal naar voren, want dan zie je vaker dat ook die hele taalkant zwak is.
M Ja.
I En D. kan eigenlijk best goed onder woorden brengen wat hij eh weet.
M Ja, ja.
I Dat wil niet zeggen dat er toch wel sprake is van een leerprobleem.
M Ja, dat is duidelijk aanwezig.
I Dat is vrij duidelijk, hij is ook eh vrij onzeker en eh hij heeft daar zelf ook moeite mee dat het niet goed gaat.
M Ja.
I Wat je wel merkte is dat als je hem dingen uitlegt en eh hem ook de tijd geeft om het rustig op zijn manier op te lossen, dat het dan wel beter gaat. Hij profiteert van uitleg.
M Hmhmm
I En hij eh ja gaat dan op die manier te werk, betekent dat als je individueel met hem werkt dat hij sneller vooruit gaat dan wanneer hij in de klas maar mee moet doen....
V Hmhmm.
I .... en eh steeds eigenlijk een beetje boven zijn niveau werkt. Want zeker met spelling zal hij toch iets boven zijn niveau werken in de klas denk ik.
M Ja.
I En het tempo van het lezen ligt wat laag ...
M Ja.
I .... en als zo'n kind dan verder onzeker is, dan eh ja dan is het voor hem veel moeilijker om dat in te halen.
M Ja.
I .... vandaar dat idee en ook het advies om hem over die, dat punt heen te helpen door individueel met hem te werken...
M Ja.
I Alleen, heeft u nog met school gepraat?
M Nee, ik ben nog niet op school geweest ....
I Nog niet.
M ... want ik dacht ik zal dit maar even afwachten, dan eh, ja ....
J Ja.
I Ja.
M .... het leek mij verstandiger.
I Ik denk dat het toch verstandig is om op school eh eens te praten en het ver ... eventueel eh als u het daarmee eens bent het verslag laten lezen.
M Ja.

J En dan moeten we denk ik eh kijken welke mogelijkheden de school zelf eh te bieden heeft

M Ja

I Of ze het probleem ook zo zien Kijk, als ze zeggen

J Ja

I er is niets aan de hand, dan

M Nou

I kunt u zeggen van nou, dat klopt niet helemaal

M ze weten wel dat er wat aan de hand is

I Ja

J Nee

M maar het was ook natuurlijk steeds gissen wat het is

I Hmhmm, hmhmm

J Ja kijk, wat betreft de hulp ehm (mompel) al zegt, wat het spellen betreft, daarvoor hebben we een bepaald eh systeem waarin eh D het spellen kan leren eh zeggen, op een betere manier dan hij het waarschijnlijk nu zal leren Dat wil zeggen daar worden eh er wordt veel meer gewerkt met regels die hij moet leren, die hij ook moet leren onthouden en die hij moet leren toepassen

M Ja

J Kijk en als dat dus eh stap voor stap gebeurt ja

M Ja

J dan, en je begint vooral bij het begin, want dat is ook nog altijd een punt dat je te ve altijd nog het probleem dat als je te hoog begint, dan blijft als het ware die basis nog eh onzeker

M Hmhmm

J Als je dat, als het goed is eh kunnen we daar wel, laten we zeggen, garanderen dat hij dus als een eh, als een ander kind kan spellen

M Ja

J Wat dat lezen betreft, gaat het vooral om het tempo ja

M Ja

J en ik denk dat ehm het ook moeilijk zou moeten zijn om als hij dat, als dat begeleid wordt, dat dat lezen eh als het langzaam gaat, gaat het iets beter, als het iets beter gaat, gaat het ook langzaam, maar de kunst is juist om bij dat lezen snelheid en nauwkeurigheid te combineren Dus dat zal ook inderdaad duidelijk kunnen verbeteren Als je dus naar het I Q kijkt denk je hij zou eigenlijk moeten kunnen presteren als een gemiddelde leerling, ja?

M Ja

J Tenminste Nou daar kan hij inderdaad beter op eh gaan lijken als we zover, als we dus een dergelijk eh trainingsprogramma met hem kunnen doen

J. the expert
A myself
Jo another researcher

J Motoriek en sensomotoriek?
A Ja Het gebied Waarom is dat van belang bij leesproblemen?
J Dat is ehm van belang, laten we zeggen aan de ene kant eh voor de ehm MBD en MBD-achtige problemen, omdat ik het eh daar altijd eh als zodanig geverifieerd wil zien Hoe het gegaan is en hoe het nog is Aan de andere kant ehm als het gaat over leerproblemen, dan weten we dat een belangrijk gedeelte van de, zo te zeggen, de algemene leerproblemen, dat die ehm geconditioneerd worden voor, door, kun je zeggen neurologische onvolmaaktheden, ja? Maar als het gaat om dyslexie wil ik het zeker weten, omdat ik dan in ieder geval het eh literatuur, de eh, de conclusie heb getrokken dat motoriek en sensomotoriek een, een correlaat is van de dyslexie, komt dus meer of minder voor
A Hmhmm
J waarbij dat meer en minder als het ware gedefinieerd is van met een correlatie nul tot een correlatie van, laten we zeggen tien tot vijftien en in de realiteit weet ik dat het vaak geassocieerd wordt met leerstoornissen of met dyslexie Dus het is ook, d heeft ook een soort differentiele betekenis met betrekking tot is het nu echt dyslexie ja of nee Eh en gezien de theorievorming die ook in Nederland eh opgeld doet, wil ik het eh daarom ook eh precies weten, zo precies mogelijk ja En dat is de achtergrond
A Dan de aparte aspecten
J De aparte aspecten?
A Ja sowieso ehm er komen ook wat, wat meer, dan denk ik nou ja technische toch wat, wat minder bekende termen in de lijst voor die ik, even zou willen definieren Wat dat voor jou betekent
J Ja Eh dan wou ik eigenlijk mee beginnen met vingerdifferentiatie Vingerdifferentiatie is een eh, eh een aspect wat in de ehm, laten we zeggen in de predictieve batterij van eh Satz een, de eerste plaats heeft ingenomen
A Hmhmm
J En dat heeft natuurlijk nogal indruk op mij gemaakt, ja Een hele lijst, ja Eerst eh de eh de hoogste voorspellende waarde Nu, vingerdifferentiatie dat eh is eigenlijk de, de, de, de iden eh eigenlijk een eh indicatie voor eh, kun je zeggen de, de stand van de ontwikkeling, van differentiatie
A Hmhmm
J van de contralaterale hemisfeer In feite probeer je dat dus daar in te meten En bij leerstoornissen veronderstel je op tijd een soort, kun je zeggen een non-differentiatie van functies of van eh
A Hmhmm
J ja, of van de anatomische gronden, of beter gezegd de eh functionele grondslagen van de functie en d t aspect meet je je eigenlijk mee Nu meet je dat zo precies als gaat Het geb het wordt eigenlijk natuurlijk als je ziet naar de, naar het begrip, wordt in feite vrij globaal eh gemeten

Maar desondanks heeft het een hoge voorspellende waarde en wil je dat weten Maar ik eh moet zeggen dat het met betrekking tot anamnese natuurlijk een wat eh ja, laten we zeggen een anamne heeft natuurlijk ook een beetje een moeilijke status, want je kunt niet zeggen hoe is het eigenlijk met de vingerdifferentiatie van een kind Die ouders denken dan eh natuurlijk niet alleen hoe die die be vingers afzonderlijk kan bewegen

A Hmhmm

J Dus je ehm geeft weleens een voorbeeld en je vraagt bijvoorbeeld kan die bijvoorbeeld dit

Jo Hmhmm

J of kan die dit Heeft u hem dat al eens zien doen Kinderen hebben toch wel eens van die spelletjes

A Hmhmm

J Maar ik moet daar voorzichtig mee zijn Ik wil niet zeggen dat ik die hier en daar echt op door vraag

Jo Laat je het kind natuurlijk wel zelf doen?

J Ja kijk, dat ga ik onderzoeken zelf he

Jo Ja, ja, ja, ja

J En dan speelt het natuurlijk eh al een andere rol

Jo Ja

J als, als het om de anamnese gaat

Jo Ja dat is ja

J Neem nu eens het lichaamsschema ja Dan ga je dus naar een volgend punt en ehm, met betrekking tot het lichaamsschema probeer je dus ook eh te zeggen of ze wel eens eh, of de ouders wel eens een keer gemerkt hebben, maar ik b , ik ben een, ben het er oo mee eens zo je zegt, eigenlijk moet al in het gesprek een soort verwijzing liggen naar, dan ga je daar als het ware daar op door en dan differentieer je zelf de vraag tot naar het eh, eh lichaamsschema

A Hm

J Ja en het lichaamschema dat weten de ouders ook niet hoe dat zit

A Hm

J Ja? Maar jevraagt je af bijvoorbeeld hebben ze eh, heeft hij ooit problemen gehad bijvoorbeeld met zich aankleden, omdat dat een vrij goede indicatie is dat het eh lichaamsschema functioneert

A En eh welke informatie wil je dan daaruit krijgen, tenminste als je d als je twijfels hebt aan het inderdaad het lichaamsschema bewustzijn Wat is voor jou inderdaad een eh antwoord wat inderdaad eh, dat je zegt van ja dat is inderdaad in het lichaamsschema iets eh niet goed geweest

J Als zij dus eh ja eigenlijk eh dat wordt inderdaad in het gesprek wordt dat zeer globaal gedaan De ouders moeten al aangeven ja hij kon nooit in zijn jas komen, of het heeft heel lang geduurd, ja, voordat hij uberhaupt zich kon omdraaien ja

A Hmhmm

J als ie zijn jas eh moest aantrekken Hij wist nooit goed hoe dat moest

A Hoe dat moest

J De verwarring dat is ook weer zo n algemeen begrip, die verwarring heeft lang geduurd

A Ja En dat eh bijvoorbeeld eh dat veters strikken? Is dat een ander aspect

J Dat valt dan onder, onder de le kun je zeggen coordinatie of handvaardigheid

A Hm

J Dat is dan iets wat eh ook in het geheugen van de ouders nog vaak wat langer, dus daar vraag je dan wat eh preciezer naar Maar dan, dat is eigenlijk het laatste wat je kan vragen voordat je vraagt naar het handschrift

A Ja

J Of naar, of potlood hanteren En dan weet ik omdat potlood hanteren ja, ehm een van de beste voorspellers is in een andere batterij

A Hmhmm

J wil ik dat dan daarom eigenlijk ook eh weten van hoe vroeg eh, kijk als de ehhhh, als de kinderen bij het potlood hanteren door het papier heen prikken, ja, dan is dat meestal een eh, zeggen een negatieve indicatie vanaf de leeftijd van vijf, zes jaar En dan is natuurlijk de vraag, is dat een symbolisch hanteren van potlood of is dat een motorisch hanteren van het potlood

Jo Hmhmm

J Goed dat moet je dus uit de voorbeelden die de ouders geven, de situatiebe schets die ze geven, moet je dan zelf concluderen

Ik moet zeggen, je eh bij die onderverdeling staat natuurlijk niet het woord 'motoriek' en "sensomotoriek" nog een keer herhaald

A Hmhmm

J Maar in feite zijn dat hoofdcategorie en bijcategorie is eigenlijk hetzelfde hè

Jo Hmhmm

J En ehm de functies die daarvan beschreven zijn, bijvoorbeeld in ehm eh in het boek leerstoornissen, die vraag je dan in feite, naar de grote motoriek

Jo Hm

J En eh ik vraag dat dan niet als een vragenlijstje, maar ik vraag eigenlijk aan de ouders wanneer eh wat hun daarbij is opgevallen en dergelijke En bij de sensomotoriek is dat eigenlijk eh ook handmotoriek En daar komt dan uiteindelijk komt dan handvaardigheid en schrijfmotoriek aan de orde

A Ja Die eh aspecten, hoe verhouden die zich tot elkaar?

J De aspecten hier hoe ver

A Ja die dus on onder dat groepje motoriek en sensomotoriek, die, je zei net zelf al iets, je gaf al iets van een, en een eh een opdeling aan he van uiteindelijk vraag je naar handvaardigheid en schrijven en schrijven Dat is natuurlijk ook omdat het in de ontwikkeling

J Hmhmm

A zeg maar het dichtste bij ligt Maar hoe houden die, die aspecten zich eh inhoudelijk me met elkaar, ja hoe, hoe zitten die met elkaar in verband?

J Waar je eigenlijk naar vraag dat is ehm, eh dat je op verschillende manieren aanwijzingen wil krijgen, of de motoriek van het kind vertraagd is

A Hmhmm

J of dat die echt verstoord is

A Hmhmm

J Dat is eigenlijk het hoofdpunt waar je naar vraagt

A Eigenlijk wel

Jo Daarbij let je op dingen die eh gebleken zijn of goede voorspelling te zijn

J Ja

Jo en eh dingen die dus specifiek eh te maken hebben straks met eh schrijven

Dat moet je zelf misschien nog wel meer eh aspecten bij motoriek en sensoriek eh sensomotoriek kunnen onderscheiden, maar deze die hier staan die zijn gewoon eh gebaseerd op, op eh de kennis die er in de literatuur is en eh het ehhhh waarschijnlijke verband straks

J Ja Dat ben ik ermee eens Dit is als lijstje is het ook niet uitputtend

A Nee

J ja, maar is het een ehm, eh ik wil ook niet zeggen een minimum, maar het is wel datgene wat je in ieder geval zou moeten weten

Jo Ja

A Ja

J Daarbij heb ik al een aantekening gemaakt bij lichaamsschema en vingerdifferentiatie

Jo Ja

J Dat wil je graag weten, maar sommige dingen die zet je dus ook voort in de diagnostiek

aarzelingen
achterstand
actieve woordenschat
afatische problemen
alliteratie
anamnese
anticiperen
auditieve discriminatie
auditieve synthese
auditieve analyse
automatische verbinding
basis
begrijpen
benoemen
bijzinnen
binden in klanken
closure
combinatie van analyse en synthese
cumulatief
decoderen
diagnostiek
differentiatie-verschijnsel
dingen kunnen benoemen
discriminatie
dyslexie
eenvoudige stellende of ontkennende zin
eigenaardigheden
erfelijkheid
foneemclusters vormen
fonologie
fout verbeteren
geheugenfunctie
geheugenspan
geledingen van zinnen
gevoel voor sterke en zwakke werkwoorden
gewone taalgebruik
grafeem-foneem koppeling
haperen
hardnekkigheid
hiërarchie
horen hoe een naam in elkaar zat
identificatie
identificeren van een klank als zodanig
intelligente kinderen
interne syntaxis
intonatie
klank kunnen determineren
klank voor klank nazeggen
klemtoon
klemtoon in de zin
klemtoon in een woord
kleuterperiode
kritische drempel
krom praten
laat begin
lang duurt
langzaam en moeizaam verwerven
leeftijd
leesproblemen
leesproces
lengte in de tijd
lengte van zinnen
lezen
medeklinker-klinker-verbindingen
medeklinker-verbindingen
metacognitieve of metalinguistische aspect
modulatie in de expressie
monotoon lezen
morfologie
morfologische aspect
naam vaak moeten spellen
namen van dagen weten
namen kunnen oproepen om zich het ding voor te stellen
namen moeten onthouden
namen kunnen oproepen als ze het ding zien
namen als zodanig onthouden
onder elkaar praten
ondergeschikt zinsverband
onevenwichtigheid
ontbinden in klanken
ontwikkeling van de taal van de eerste jaren
ontwikkelingseigenaardigheden
ontwikkelingskenmerken
oproepen van de woordbetekenissen
oproepen van woordbetekenis
opvallende kenmerken
ouders
positieve indicaties
precisie van de naam onthouden
produceren
receptieve woordenschat
recht praten
redardatie in de taalontwikkeling
remming van binnenuit
remming van buitenaf
rijmen
samenvoegen tot klanken
schrijven
semantisch aspect
semantische systeem
seriele ordening
slijtage in woorden
snelle feedback geven op je taalervaring
spellingsproblemen
spontaan
spontaan fouten
spreken
structureel taalprobleem
syntactisch
syntaxis
taal voldoende ontwikkeld
taalexpressie
taalgevoel
taalontwikkeling rond de derde verjaardag
taalontwikkeling
taaltests voor kinderen
taalverwaarloosde kinderen
uitvallers
varianten
verbasteren
verschil tussen klanken horen
verschillen tussen kinderen
verschillen tussen woorden horen
versprekingen
vertraging
vervloeien
visueel verbale koppelingen
visuo-verbale koppelingen
voorbeelden
voorbeelden ontlokken
welgevormdheid van zinnen
woord vervoeging
woord voeren tegen een volwassene
woordbetekenis
woordenschat
woordverbuigingen
woordvinding
woordvindingsprobleem
woordvorming
woordvormingsproblemen
zeven criteria
zinnen
zuiver uitspreken
zwakbegaafde kinderen

lichamelijk functioneren

buikpijn
hoofdpijn
lusteloos zijn
zwangerschapsperiode
geboorte
kinderziekten
lichamelijke ontwikkeling
motorische onrust
beweeglijkheid
zintuigen
- slecht horen
- doof zijn
- slecht zien
- lui oog
- prismabril

motoriek

grote motoriek
- evenwicht
- lichaamsschema
  - jas aantrekken
  - aankleden
- bewegen
  - veel vallen
  - hinkelen
  - fietsen
  - zwemmen
  - bal gooien en vangen
  - houterig bewegen
  - laat los lopen
  - rolschaatsen
  - lang fietsen met zijwielen

sensomotoriek
- handvaardigheid
  - veters strikken
  - knippen
  - tekenen
- schrijfmotoriek
  - potloodgreep
  - potlooddruk
  - handschrift
- vingerdifferentiatie
  - benoemen van vingers (met en zonder aanraking)

ruimtelijke oriëntatie en geheugen

vakantiebestemming herkennen
van te voren reeds weten wat men men daar kan aantreffen
figuren op het platte vlak
driedimensionaal afgebeelde figuren
orientatie in de voorgestelde ruimte
- precies weten hoe te rijden
- weten waar dingen te vinden zijn
- weten hoe je ergens kunt komen
- links-rechts onderscheid

lateraliteit

rechts en links benoemen
- links-rechts onderscheid

handigheid
- rechtshandig
- linkshandig
- ambidextriteit

temporele orde

praktische temporele orde
- volgorde van gebeurtenissen weten
- temporele volgorde van links naar rechts weten
  - scannen van links naar rechts
  - scanning bij leestaken
    - strips lezen
    - letters schrijven vanuit de verkeerde richting
    - omdraaiingen van cijfers of letters

verbale temporele orde
- een verhaal kriskras vertellen
- onthouden van de dagen weken maanden

visuele waarneming

onthouden van afbeeldingen
- beschrijven van details op vakantie
- visuele herkenning
- visueel geheugen
  - onthouden van formules
  - topografie
  - meefluisteren bij schrijven van woorden

visuele analyse en synthese
- puzzelen
- memory-spel

taal

fonologie
- discriminatie
  - verschillen tussen klanken horen
  - verschillen tussen woorden horen
- klankidentificatie
- analyse
  - horen hoe een naam in elkaar zit
- synthese
  - vormen van clusters
- combinatie van analyse en synthese
  - alliteratie
  - rijmen
- objectivatie
- woordherkenning
- auditief geheugen
  - klanken onthouden
    - klank voor klank nazeggen
  - onthouden van namen
    - namen van kleuren onthouden
    - namen van kinderen in de klas onthouden
  - klankvolgorde onthouden
    - wesp en weps verwarren
    - medeklinker-klinker verbindingen onthouden
    - klinker-klinker verbindingen onthouden
  - gelezen woord wordt weer vergeten
  - klank-letter koppelingen

syntaxis
- lengte van zinnen
  - niet meer spreken dan noodzakelijk
  - vermijden van lange zinnen
  - niet in zinnen spreken
- welgevormdheid van zinnen
  - welgevormdheid binnen zinnen
    - geen onderwerp-gezegde-voorwerp zinnen
  - welgevormdheid tussen hoofd- en bijzinnen
    - ondergeschikt zinsverband
  - leren van grammatica in tweede taal

morfologie
- neologismen
- zuiver uitspreken
- woorden gescheiden van elkaar uitspreken
- woorden omdraaien
- woordvervoeging
  - sterke en zwakke werkwoorden
- woordverbuiging
  - zelfstandige, bijvoeglijke en bezittelijke naamwoorden
  - meervoudsvormen
  - verkleinwoorden

semantiek
- taalexpressie
  - klemtoon binnen een woord
  - klemtoon binnen een zin
    - monotoon lezen
- woordenschat
  - receptieve woordenschat
    - vaak extra uitleg nodig hebben
    - ouders praten extra eenvoudig
    - instructie begrijpen
  - actieve woordenschat
    - ouders moeten goede verstaanders van het kind zijn
    - leren van woordjes in een vreemde taal
- woordbetekenis

verloop van taalontwikkeling

beginpunt van taal

haperen of aarzelen bij spreken

taalfouten

verbasteren van taal

schools functioneren

lezen
- intonatie
- klemtoon
- lezen wat er staat
- begrijpend verklanken van woorden
- melodie in het lezen
- vloeiendheid van lezen
- typische leesfouten
- gelezen woord wordt weer vergeten
- langzaam lezen
- filmisch lezen
- globaal lezen
- slordig lezen
- aanvankelijk lezen
- nauwkeurig lezen
- klank-letter koppelingen
  - langdurig kijken naar grafemen
  - klinkers in een gesloten lettergreep
  - klinkers met een gering auditief verschil
  - moeilijke beginmedeklinkers
  - klinkers en medeklinkers met een gering visueel verschil
- griekse alfabet aanleren
- spellend lezen
  - eenlettergrepig spellend lezen
    - klinker medeklinker woorden
    - medeklinker klinker woorden
    - medeklinker klinker medeklinker woorden
  - meerlettergrepig spellend lezen
- herkennend lezen
  - eenlettergrepig herkennend lezen
    - visuele synthese van lettergroepen
    - directe herkenning van mkm woorden
    - samengestelde klankzuivere woorden
  - meerlettergrepig herkennend lezen
- spellend en herkennend lezen
  - klankzuivere mkmm woorden
  - klankzuivere mmkm woorden
  - uitbreiding van klankzuivere eenlettergrepige woorden
- tempo lezen
  - eenlettergrepige tempo lezen
  - meerlettergrepig tempo lezen
- zinnen lezen
  - eenlettergrepige zinnen lezen
  - meerlettergrepige zinnen lezen
- teksten lezen
- begrijpend lezen

rekenen
- werktempo bij rekenen
- breuken bij rekenen
- inhoudsmaten bij rekenen
- bussommen
- tafels van vermenigvuldiging onthouden

spellen
- typische spellingfouten
- letters spellen
  - begrippen
  - vier lange en vijf korte klinkers
  - medeklinkers exclusief tweeklanken
  - combinaties van reeds geoefende klinkers en medeklinkers
  - tweeklanken
  - medeklinkers
- woorden spellen
  - mkm woorden
  - kmm woorden
  - mkmm woorden
  - mmkm woorden
  - klankzuivere eenlettergrepige woorden
  - ou-ouw-au-auw woorden
  - kennis van begrippen
  - kennis van hoofdregelsysteem
  - uitbreiding hoofdregels
  - woorden met specifieke uitgangen en meervouden
  - moeilijke woorden met d en toonloze e op het eind
  - woorden beginnend met ge be ver en te
  - vreemde woorden
  - woorden spellen van vreemde taal

- zinnen ontleden
  - bepalen en verlengen en verkorten van zinnen
  - bepalen wat onderwerp is
  - bepalen wat werkwoord is
  - bepalen wat tegenwoordige en verleden tijd is
  - bepalen van de persoonsvorm
  - onderscheid tussen zwakke en sterke werkwoorden
  - bepalen van het hele werkwoord
  - onderscheid in de werkwoordsgroepen den, ten en andere
  - onderscheid bepalende, vragende zin en plaats van de persoonsvorm
  - bepalen van de persoon in 6 typen persoonszinnen en het enkel of meervoud van de persoon bepalen
  - verleden tijd vorming via de regels van het kofschip of fokschaap
  - schrijfregels voor persoonsvormen in de tegenwoordige tijd
  - schrijfregels voor persoonsvormen in de verleden tijd
- verhaal schrijven

schrijfmotoriek
- potloodgreep
- potlooddruk
- handschrift

cognitief functioneren

intelligentie
- algemeen
  - aanleren van nieuwe dingen
  - vaak extra uitleg nodig hebben
- tweefactoriele indeling
  - verbale intelligentie
  - performale intelligentie
- driefactoriele indeling
  - verbale factor
  - visueel ruimtelijke factor
  - concentratiefactor

monitoring
- controleren van werk
- systematisch versus chaotisch werken
- gevoelig zijn voor ondersteuning
- creatief of star met een probleem omgaan
- hardop meespellen bij schrijven
- concentratie
  - concentratiefactor
  - dagdromen
  - sterk wisselende prestaties binnen een test
  - snel afgeleid worden
  - motorisch onrustig zijn
  - dips hebben
  - korte spanningsboog hebben
  - beweeglijkheid
  - werktempo
- geheugen
  - algemeen
    - rehearsal
    - chunking
    - vergeetachtigheid
    - van buiten leren
    - tafels van vermenigvuldiging
    - jaartallen onthouden
  - visueel geheugen
    - onthouden van formules
    - topografie
    - meefluisteren bij schrijven van woorden
  - auditief geheugen
    - klanken onthouden
      - klank voor klank nazeggen
    - onthouden van namen
      - namen van kleuren onthouden
      - namen van kinderen in de klas onthouden
    - klankvolgorde onthouden
      - wesp en weps verwarren
      - medeklinker-klinker verbindingen onthouden
      - klinker-klinker verbindingen onthouden
    - gelezen woord wordt weer vergeten
    - klank-letter koppelingen

aversie tegen leertaken
- motivatie bij verschillende soorten taken

taakwerkhouding
- tegen de taak opzien
- druk of chaotisch zijn
- vaak hulp nodig hebben
- geen verantwoordelijkheid nemen
- snel gefrustreerd zijn
- doorzettingsvermogen

- structuur aanbrengen in werk
- wisselende inzet
- slordig zijn
- huiswerkaanpak
- weglopen uit taaksituatie

persoonlijk functioneren

aversie tegen leertaken
- motivatie bij verschillende soorten taken

weglopen uit taaksituatie
temperament
faalangst
- buikpijn
- hoofdpijn
- blokkeren tijdens testsituatie
- geen fouten durven maken
- niet beginnen met een taak
- spellend blijven lezen
- onzeker
- snel om hulp vragen

interesse
- interesse in auditieve of visuele taken

inzicht in persoonlijk functioneren
eigenwaarde
verlegenheid
koppig zijn
eigenwijs zijn
vrij spelen

sociaal functioneren

positie binnen gezin
- gezinsvolgorde
- identificatie mogelijk met dyslexie-ouder
- echtscheiding van ouders

interactie met opvoeders
- communicatie met opvoeders
- opvoeding
- zindelijkheid
- eten
- slapen
- sociaal wenselijk gedrag vertonen
- aandacht vragen

omgang met leeftijdgenoten
omgang met school en docenten

visueel-verbale koppelingen

voorwerpen benoemen
moeite hebben om op woorden te komen
veel "dinges" zeggen
haperen bij normale woorden
namen aan voorstellingen koppelen
kleuren benoemen
namen van kinderen uit de klas noemen
de juiste woorden en zinnen vinden
verwoorden van gebeurtenissen
semantiek
- taalexpressie
  - klemtoon binnen een woord
  - klemtoon binnen een zin
  - monotoon lezen
- woordenschat
  - receptieve woordenschat
  - vaak extra uitleg nodig hebben
  - ouders praten extra eenvoudig
  - instructie begrijpen
  - actieve woordenschat
  - ouders moeten goede verstaanders van het kind zijn
  - leren van woordjes in een vreemde taal
- woordbetekenis

fonologie
- discriminatie
  - verschillen tussen klanken horen
  - verschillen tussen woorden horen
- klankidentificatie
- analyse
  - horen hoe een naam in elkaar zit
- synthese
  - vormen van clusters
- combinatie van analyse en synthese
  - alliteratie
  - rijmen
- objectivatie
- woordherkenning

- auditief geheugen
  - klanken onthouden
    - klank voor klank nazeggen
  - onthouden van namen
    - namen van kleuren onthouden
    - namen van kinderen in de klas onthouden
  - klankvolgorde onthouden
    - wesp en weps verwarren
    - medeklinker-klinker verbindingen onthouden
    - klinker-klinker verbindingen onthouden
  - gelezen woord wordt weer vergeten
  - klank-letter koppelingen

visuele waarneming

- onthouden van afbeeldingen
  - beschrijven van details op vakantie
  - visuele herkenning
  - visueel geheugen
    - onthouden van formules
    - topografie
    - meefluisteren bij schrijven van woorden
- visuele analyse en synthese
  - puzzelen
  - memory-spel

spraak

verloop van spraakontwikkeling
stotteren
moeite met uitspreken
onduidelijk spreken
binnenmonds spreken

visuo-motoriek

motoriek

- grote motoriek
  - evenwicht
  - lichaamsschema
    - jas aantrekken
    - aankleden
  - bewegen
    - veel vallen
    - hinkelen
    - fietsen
    - zwemmen
    - bal gooien en vangen
    - houterig bewegen
    - laat los lopen
    - rolschaatsen
    - lang fietsen met zijwielen
- sensomotoriek
  - handvaardigheid
    - veters strikken
    - knippen
    - tekenen
  - schrijfmotoriek
    - potloodgreep
    - potlooddruk
    - handschrift
  - vingerdifferentiatie
    - benoemen van vingers (met en zonder aanraking)

visuele waarneming

- onthouden van afbeeldingen
  - beschrijven van details op vakantie
  - visuele herkenning
  - visueel geheugen
    - onthouden van formules
    - topografie
    - meefluisteren bij schrijven van woorden
- visuele analyse en synthese
  - puzzelen
  - memory-spel

achievement motivation scale for children
alliteratieproefje
avi-leeskaarten
bannatyne visio spatial memory test
bourdon vos test
childrens apperception test
cito begrijpend lezen 3-4-5
cito lees en begrijp 1-2
cloze toets begrijpend lezen
coloured progressive matrices
columbus
competentie belevingsschaal voor kinderen
davis test voor begrijpend lezen
diagnostisch rekenonderzoek van erp
differentiele aanleg test (8 subtests)
een-minuut test
family relation test
familie in tieren
groninger schoolonderzoek 2 (8 subtests)
groninger schoolonderzoek 3 (13 subtests)
groninger schoolonderzoek 4-6 (13 subtests)
groninger schoolonderzoek 7-8 (14 subtests)
harris test of lateral dominance
kijkbewijs henneman
de nieuwe kerk henneman
i-e lijst
informele test links-rechts benoemen
instapproeven in den kleef (12 subtests)
junior nederlandse persoonlijkheids vragenlijst
konzentrastions verlauf test
leesvaardigheidstest wiegersma
leesvoorwaardentoets
leidse diagnostische test (5 subtests)
letterdictee
memory for designs test
moneys test of directional sense
motor free visual perception test
nip gates leesrijpheidstest
prestatie motivatie test voor kinderen
reversal test
rijmproefje
rispens proeven (3 subtests)
schiedamse rekentest
schoolvragenlijst
spellingtoetsen van aap tot hierarchie
ssat
stanford binet intelligence scale geheugen subtests
stilleestest 3-4-6 bakker
stroop-kleur-woord test
cito technisch lezen 1-2
letters lezen
test of visual perception
taaltests voor kinderen (10 subtests)
verhaaltje schrijven
visual aural digit span test
visual motor gestalt test
visual motor integration test
wisc-r (12 subtests)
zinnenaanvultest
zinnendictee van der wissel

rule specificiteitscriterium

if [the probleem of visueel_verbale_koppelingen is ja or
the probleem of haperen_of_aarzelen_bij_spreken is ja or
the probleem of verloop_van_taalontwikkeling is ja or
the probleem of beginpunt_van_taal is ja or
the probleem of taalfouten is ja or
the probleem of verbasteren_van_taal is ja or
the probleem of auditief_geheugen is ja or
the probleem of morfologie is ja or
the probleem of syntaxis is ja] and
[the probleem of lezen is ja or
the probleem of spellen is ja] and
[the obsprobleem of rehearsal is ja or
the obsprobleem of meefluisteren_bij_woorden is ja or
the obsprobleem of langdurig_kijken_naar_grafemen is ja or
the obsprobleem of articulatie is ja or
the obsprobleem of precisie is ja or
the obsprobleem of woordanalyse is ja or
the obsprobleem of snelheid is ja or
the obsprobleem of oog_stem_spanne is ja or
the obsprobleem of zinsmelodie is ja or
the obsprobleem of expressiviteit is ja or
the obsprobleem of intonatie is ja or
the obsprobleem of chunking is ja or
the obsprobleem of concentratie_op_de_tekst is ja or
the obsprobleem of geheugen_voor_aaneenschakeling_van_gebeurtenissen is ja or
the obsprobleem of moeite_hebben_om_op_woorden_te_komen is ja or
the obsprobleem of veel_dinges_zeggen is ja or
the obsprobleem of haperen_bij_normale_woorden is ja] and
[[the score of leesvaardigheidstest_wiegersma includes a Score and the prestatie_bij_dyslexie of leesvaardigheidstest_wiegersma includes a Score] or
[the score of een_minuut_test includes a Score and the prestatie_bij_dyslexie of een_minuut_test includes a Score] or
[the score of tvk_auditieve_synthesetest includes a Score and the prestatie_bij_dyslexie of tvk_auditieve_synthesetest includes a Score] or
[the score of tvk_auditieve_woorddiscriminatie includes a Score and the prestatie_bij_dyslexie of tvk_auditieve_woorddiscriminatie includes a Score] or
[the score of tvk_woordherkenning includes a Score and the prestatie_bij_dyslexie of tvk_woordherkenning includes a Score] or
[the score of nipg_gates_leesrijpheidstest includes a Score and the prestatie_bij_dyslexie of nipg_gates_leesrijpheidstest includes a Score] or

[the score of leesvoorwaardentoets_lvt includes a Score and the prestatie_bij_dyslexie of leesvoorwaardentoets_lvt includes a Score] or
[the score of instapproeven_auditief_analyseren includes a Score and the prestatie_bij_dyslexie of instapproeven_auditief_analyseren includes a Score] or
[the score of instapproeven_auditief_synthetiseren includes a Score and the prestatie_bij_dyslexie of instapproeven_auditief_synthetiseren includes a Score] or
[the score of instapproeven_klankdiscriminatie includes a Score and the prestatie_bij_dyslexie of instapproeven_klankdiscriminatie includes a Score] or
[the score of instapproeven_klankidentificatie includes a Score and the prestatie_bij_dyslexie of instapproeven_klankidentificatie includes a Score] or
[the score of instapproeven_objectivering includes a Score and the prestatie_bij_dyslexie of instapproeven_objectivering includes a Score] or
[the score of instapproeven_woorddiscriminatie includes a Score and the prestatie_bij_dyslexie of instapproeven_woorddiscriminatie includes a Score] or
[the score of instapproeven_woorddictee includes a Score and the prestatie_bij_dyslexie of instapproeven_woorddictee includes a Score] or
[the score of instapproeven_zinsdictee includes a Score and the prestatie_bij_dyslexie of instapproeven_zinsdictee includes a Score] or
[the score of instapproeven_overschrijven includes a Score and the prestatie_bij_dyslexie of instapproeven_overschrijven includes a Score] or
[the score of instapproeven_woorden_lezen includes a Score and the prestatie_bij_dyslexie of instapproeven_woorden_lezen includes a Score] or
[the score of instapproeven_begrijpend_lezen includes a Score and the prestatie_bij_dyslexie of instapproeven_begrijpend_lezen includes a Score] or
[the score of instapproeven_zinnen_lezen includes a Score and the prestatie_bij_dyslexie of instapproeven_zinnen_lezen includes a Score] or
[the score of rispens_auditief_geheugen includes a Score and the prestatie_bij_dyslexie of rispens_auditief_geheugen includes a Score] or
[the score of rispens_auditieve_analyse includes a Score and the prestatie_bij_dyslexie of rispens_auditieve_analyse includes a Score] or
[the score of rispens_auditieve_synthese includes a Score and the prestatie_bij_dyslexie of rispens_auditieve_synthese includes a Score] or
[the score of rispens_combinatieproef includes a Score and the prestatie_bij_dyslexie of rispens_combinatieproef includes a Score] or
[the score of alliteratieproefje includes a Score and the prestatie_bij_dyslexie of alliteratieproefje includes a Score] or
[the score of rijmproefje includes a Score and the prestatie_bij_dyslexie of rijmproefje includes a Score] or
[the score of test_letters_lezen includes a Score and the prestatie_bij_dyslexie of test_letters_lezen includes a Score] or
[the score of avi_leesniveaus includes a Score and the prestatie_bij_dyslexie of avi_leesniveaus includes a Score] or
[the score of technisch_lezen_1_en_2 includes a Score and the prestatie_bij_dyslexie of technisch_lezen_1_en_2 includes a Score] or
[the score of cito_begrijpend_lezen_3_4_5 includes a Score and the prestatie_bij_dyslexie of cito_begrijpend_lezen_3_4_5 includes a Score] or

[the score of cito_lees_en_begrijp_1_en_2 includes a Score and the prestatie_bij_dyslexie of cito_lees_en_begrijp_1_en_2 includes a Score] or
[the score of stilleestest_3_4_6_bakker includes a Score and the prestatie_bij_dyslexie of stilleestest_3_4_6_bakker includes a Score] or
[the score of letterdictee includes a Score and the prestatie_bij_dyslexie of letterdictee includes a Score] or
[the score of spellingtoetsen_van_aap_tot_hierarchie includes a Score and the prestatie_bij_dyslexie of spellingtoetsen_van_aap_tot_hierarchie includes a Score] or
[the score of verhaaltje_schrijven includes a Score and the prestatie_bij_dyslexie of verhaaltje_schrijven includes a Score] or
[the score of zinnendictee_van_der_wissel includes a Score and the prestatie_bij_dyslexie of zinnendictee_van_der_wissel includes a Score] or
[the score of davis_test_voor_begrijpend_lezen includes a Score and the prestatie_bij_dyslexie of davis_test_voor_begrijpend_lezen includes a Score] or
[the score of cloze_toets_begrijpend_lezen includes a Score and the prestatie_bij_dyslexie of cloze_toets_begrijpend_lezen includes a Score] or
[the score of kijkbewijs_henneman includes a Score and the prestatie_bij_dyslexie of kijkbewijs_henneman includes a Score] or
[the score of de_nieuwe_kerk_henneman includes a Score and the prestatie_bij_dyslexie of de_nieuwe_kerk_henneman includes a Score] or
[the score of differentiele_aanleg_test_woordenlijst includes a Score and the prestatie_bij_dyslexie of differentiele_aanleg_test_woordenlijst includes a Score] or
[the score of differentiele_aanleg_test_woordbeeld includes a Score and the prestatie_bij_dyslexie of differentiele_aanleg_test_woordbeeld includes a Score] or
[the score of differentiele_aanleg_test_zinnen includes a Score and the prestatie_bij_dyslexie of differentiele_aanleg_test_zinnen includes a Score] or
[the score of differentiele_aanleg_test_analogieen includes a Score and the prestatie_bij_dyslexie of differentiele_aanleg_test_analogieen includes a Score]]
then specificiteitscriterium of dyslexie becomes true

rule normaliteitscriterium
if prestatie_bij_dyslexie of wisc_r includes the score of wisc_r
then normaliteitscriterium of dyslexie becomes true

rule discrepantiecriterium
if the specificiteitscriterium of dyslexie is true and
the normaliteitscriterium of dyslexie is true
then discrepantiecriterium of dyslexie becomes true

rule exclusiviteitscriterium
if not [conclusie slechtziendheid voldoet or
conclusie slechthorendheid voldoet or
conclusie doofheid voldoet or
conclusie grote_motoriek_probleem voldoet or
conclusie mbd voldoet or
conclusie emotioneel_probleem voldoet or
conclusie probleem_met_docent voldoet or
conclusie minderwaardigheidsgevoelens voldoet or
conclusie motivatieprobleem voldoet or

conclusie faalangstig voldoet or
conclusie rekenvaardigheid voldoet or
conclusie rekenen_als_secundair_probleem voldoet]
then exclusiviteitscriterium of dyslexie becomes true

rule taalontwikkelingscriterium

if [the probleem of fonologie is ja or
the probleem of semantiek is ja or
the probleem of syntaxis is ja or
the probleem of morfologie is ja or
the probleem of beginpunt_van_taal is ja or
the probleem of verloop_van_taalontwikkeling is ja or
the probleem of haperen_of_aarzelen_bij_spreken is ja or
the probleem of taalfouten is ja or
the probleem of verbasteren_van_taal is ja or
[the score of tvk_auditieve_synthesetest includes a Score and the prestatie_bij_dyslexie of tvk_auditieve_synthesetest includes a Score] or
[the score of tvk_auditieve_woorddiscriminatie includes a Score and the prestatie_bij_dyslexie of tvk_auditieve_woorddiscriminatie includes a Score] or
[the score of tvk_woordherkenning includes a Score and the prestatie_bij_dyslexie of tvk_woordherkenning includes a Score] or
[the score of tvk_syntactisch_produktief includes a Score and the prestatie_bij_dyslexie of tvk_syntactisch_produktief includes a Score] or
[the score of tvk_syntactisch_receptief includes a Score and the prestatie_bij_dyslexie of tvk_syntactisch_receptief includes a Score] or
[the score of tvk_woordenschat_keuzetest includes a Score and the prestatie_bij_dyslexie of tvk_woordenschat_keuzetest includes a Score] or
[the score of tvk_woordenschat_produktietest includes a Score and the prestatie_bij_dyslexie of tvk_woordenschat_produktietest includes a Score] or
[the score of tvk_woordvormen_beoordeling includes a Score and the prestatie_bij_dyslexie of tvk_woordvormen_beoordeling includes a Score] or
[the score of tvk_woordvormen_produktie includes a Score and the prestatie_bij_dyslexie of tvk_woordvormen_produktie includes a Score] or
[the score of instapproeven_auditief_analyseren includes a Score and the prestatie_bij_dyslexie of instapproeven_auditief_analyseren includes a Score] or
[the score of instapproeven_auditief_synthetiseren includes a Score and the prestatie_bij_dyslexie of instapproeven_auditief_synthetiseren includes a Score] or
[the score of instapproeven_klankdiscriminatie includes a Score and the prestatie_bij_dyslexie of instapproeven_klankdiscriminatie includes a Score] or
[the score of instapproeven_klankidentificatie includes a Score and the prestatie_bij_dyslexie of instapproeven_klankidentificatie includes a Score] or
[the score of instapproeven_objectivering includes a Score and the prestatie_bij_dyslexie of instapproeven_objectivering includes a Score] or
[the score of instapproeven_woorddiscriminatie includes a Score and the prestatie_bij_dyslexie of instapproeven_woorddiscriminatie includes a Score] or
[the score of rispens_auditief_geheugen includes a Score and the prestatie_bij_dyslexie of rispens_auditief_geheugen includes a Score] or

[the score of rispens_auditieve_analyse includes a Score and the prestatie_bij_dyslexie of rispens_auditieve_analyse includes a Score] or
[the score of rispens_auditieve_synthese includes a Score and the prestatie_bij_dyslexie of rispens_auditieve_synthese includes a Score] or
[the score of rispens_combinatieproef includes a Score and the prestatie_bij_dyslexie of rispens_combinatieproef includes a Score] or
[the score of differentiele_aanleg_test_woordenlijst includes a Score and the prestatie_bij_dyslexie of differentiele_aanleg_test_woordenlijst includes a Score] or
[the score of differentiele_aanleg_test_woordbeeld includes a Score and the prestatie_bij_dyslexie of differentiele_aanleg_test_woordbeeld includes a Score] or
[the score of differentiele_aanleg_test_zinnen includes a Score and the prestatie_bij_dyslexie of differentiele_aanleg_test_zinnen includes a Score] or
[the score of differentiele_aanleg_test_analogieen includes a Score and the prestatie_bij_dyslexie of differentiele_aanleg_test_analogieen includes a Score]]
then taalontwikkelingscriterium of dyslexie becomes true

rule dysharmonisch_intelligentieprofiel
if [the score of wisc_r_verbale_testen includes a Score1 and the score of wisc_r_performale_testen includes a Score2 and Score1 is less than Score2 and Score2 minus Score1 is greater than 15] or
[the score of visueel_ruimtelijk_factor_wisc_r includes a Score3 and the score of verbale_factor_wisc_r includes a Score4 and the score of concentratie_informatieverwerkings_sequentiele_factor_wisc_r includes a Score5 and Score3 is greater than Score4 and Score4 is greater than Score5]
then dysharmonisch_intelligentieprofiel of dyslexie becomes true

rule erfelijkheidscriterium
if $ lookup(erfelijk,X,ja)
then erfelijkheidscriterium of dyslexie becomes true

relation conclusie Conclusie voldoet
if $ isa_default(conclusie,Concept,Conclusie)
and $ is_voldaan(Concept)

relation conclusie Conclusie voldoet
if $ isa_default(conclusie,Concept,Conclusies)
and $ lst(Conclusies)
and $ on(Conclusie,Conclusies)
and $ is_voldaan(Concept)

rule oplossing_a
if the specificiteitscriterium of dyslexie is true, and
the normaliteitscriterium of dyslexie is true, and
the discrepantiecriterium of dyslexie is true, and
the exclusiviteitscriterium of dyslexie is true, and
the taalontwikkelingscriterium of dyslexie is true, and
the dysharmonisch_intelligentieprofiel of dyslexie is true, and
the erfelijkheidscriterium of dyslexie is true
then oplossing_a becomes true
and $ lookup(naam,personalia,Naamlijst)
and $ zoeknaam(Naamlijst,Roepnaam)

```
    and $ message({'Er',lijkt,sprake,te,zijn,van,dyslexie,bij,Roepnaam,' '})
    and $ geef_behand(Roepnaam,nothing)
rule oplossing_b
    if the specificiteitscriterium of dyslexie is true, and
       the normaliteitscriterium of dyslexie is true, and
       the discrepantiecriterium of dyslexie is true, and
       [ conclusie slechtziendheid voldoet or
           conclusie slechthorendheid voldoet or
           conclusie muddenoorontsteking voldoet or
           conclusie grote_motoriek_probleem voldoet or
           conclusie mbd voldoet or
           conclusie probleem_met_docent voldoet or
           conclusie rekenvaardigheid voldoet ], and
       the taalontwikkelingscriterium of dyslexie is true, and
       the dysharmonisch_intelligentieprofiel of dyslexie is true, and
       the erfelijkheidscriterium of dyslexie is true
    then oplossing_b becomes true
    and $ lookup(naam,personalia,Naamlijst)
    and $ zoeknaam(Naamlijst,Roepnaam)
    and $ geef_probleem_info({'Er',lijkt,sprake,te,zijn,van,dyslexie,bij,Roepnaam,',',de,situatie,
          is,echter,gecompliceerd,doordat,er,de,volgende,problemen,ook, spelen '},{slechtziend-
          heid,slechthorendheid,doofheid,grote_motoriek_probleem,mbd,probleem_met_docent,
          rekenvaardigheid})
    and $ geef_behand(Roepnaam,{slechtziendheid,slechthorendheid,doofheid,grote_moto-
          riek_probleem,mbd,probleem_met_docent, rekenvaardigheid})
rule oplossing_c
    if the specificiteitscriterium of dyslexie is true, and
       the normaliteitscriterium of dyslexie is true, and
       the discrepantiecriterium of dyslexie is true, and
       [ conclusie emotioneel_probleem voldoet or
           conclusie minderwaardigheidsgevoelens voldoet or
           conclusie motivatieprobleem voldoet or
           conclusie faalangstig voldoet or
           conclusie rekenen_als_secundair_probleem voldoet or
           conclusie scanning_bij_leestaken_als_secundair_probleem voldoet ], and
       the taalontwikkelingscriterium of dyslexie is true, and
       the dysharmonisch_intelligentieprofiel of dyslexie is true, and
       the erfelijkheidscriterium of dyslexie is true
    then oplossing_c becomes true
    and $ lookup(naam,personalia,Naamlijst)
    and $ zoeknaam(Naamlijst,Roepnaam)
    and $ geef_probleem_info({'Er',lijkt,sprake,te,zijn,van,dyslexie,bij,Roepnaam,',',er,zijn,ech-
          ter,ook,secundaire,problemen,',',veroorzaakt,door,de,'dyslexie  De',problemen,'zijn '},-
          {emotioneel_probleem,minderwaardigheidsgevoelens,motivatieprobleem,faalangstig,-
          rekenen_als_secundair_probleem,scanning_bij_leestaken_als_secundair_probleem})
```

```
    and $ geef_behand(Roepnaam,[emotioneel_probleem,minderwaardigheidsgevoelens,motiva-
          tieprobleem,faalangstig,rekenen_als_secundair_probleem,scanning_bij_leestaken_als_
          secundair_probleem]) .
rule oplossing_d
    if the specificiteitscriterium of dyslexie is true, and
       not the exclusiviteitscriterium of dyslexie is true, and
       [ not the normaliteitscriterium of dyslexie is true or
          not the discrepantiecriterium of dyslexie is true or
          not the taalontwikkelingscriterium of dyslexie is true or
          not the dysharmonisch_intelligentieprofiel of dyslexie is true or
          not the erfelijkheidscriterium of dyslexie is true ]
    then oplossing_d becomes true
    and $ lookup(naam,personalia,Naamlijst)
    and $ zoeknaam(Naamlijst,Roepnaam)
    and $ geef_probleem_info(['Er',is,sprake,van,een,leesprobleem,met,onbekende,oorzaak,en,-
          er,spelen,ook,nog,andere,problemen,bij,Roepnaam,'. Deze',problemen,'zijn:'],[slecht-
          ziendheid,slechthorendheid,doofheid,grote_motoriek_probleem,mbd,emotioneel_pro-
          bleem,probleem_met_docent,minderwaardigheidsgevoelens,motivatieprobleem,faal-
          angstig,rekenvaardigheid,rekenen_als_secundair_probleem])
     and $ geef_behand(Roepnaam,[slechtziendheid, slechthorendheid,doofheid,grote_moto-
          riek_probleem,mbd,emotioneel_probleem,probleem_met_docent,minderwaardigheids-
          gevoelens,motivatieprobleem,faalangstig,rekenvaardigheid,rekenen_als_secundair_-
          probleem]) .
rule oplossing_e
    if the specificiteitscriterium of dyslexie is true, and
       the normaliteitscriterium of dyslexie is true, and
       the discrepantiecriterium of dyslexie is true, and
       the exclusiviteitscriterium of dyslexie is true, and
       the taalontwikkelingscriterium of dyslexie is true, and
       [ the score of wisc_r_verbale_testen includes a Score1 and the score of
          wisc_r_performale_testen includes a Score2 and [ Score1 is less than Score2 or Score1 is
          equal to Score2 ] and Score2 minus Score1 is less than 15 ], and
       the erfelijkheidscriterium of dyslexie is true
    then oplossing_e becomes true
    and $ lookup(naam,personalia,Naamlijst)
    and $ zoeknaam(Naamlijst,Roepnaam)
    and $ geef_probleem_info(['Er',lijkt,sprake,te,zijn,van,dyslexie,bij,Roepnaam,';',er,is,ech-
          ter,geen,verschil,aangetoond,tussen,de,'visuo-spatiele',en,verbale,'factor.Een',verkla-
          ring,hiervoor,zou,kunnen,zijn,dat,Roepnaam,gevoelig,is,voor,tijdslimieten,en,hierdoor,
          de,performale,score,gedrukt,'wordt.'],nothing)
    and $ geef_behand(Roepnaam,nothing).
rule oplossing_f
    if the specificiteitscriterium of dyslexie is true, and
       the normaliteitscriterium of dyslexie is true, and
       the discrepantiecriterium of dyslexie is true, and
       the exclusiviteitscriterium of dyslexie is true, and
```

```
        not the taalontwikkelingscriterium of dyslexie is true, and
        not the dysharmonisch_intelligentieprofiel of dyslexie is true, and
        not the erfelijkheidscriterium of dyslexie is true
    then oplossing_f becomes true
    and $ lookup(naam,personalia,Naamlijst)
    and $ zoeknaam(Naamlijst,Roepnaam)
    and $ message(['Er',is,geen,sprake,van,dyslexie,',',echter,wel,van,een,leerstoornis,bij,Roep-
          naam,' '])
    and $ geef_behand(Roepnaam,nothing) .
rule oplossing_g
    if the specificiteitscriterium of dyslexie is true
    then oplossing_g becomes true
    and $ lookup(naam,personalia,Naamlijst)
    and $ zoeknaam(Naamlijst,Roepnaam)
    and $ message(['Er',is,sprake,van,een,leesprobleem,met,onbekende,oorzaak,bij,Roepnaam,' '])
    and $ geef_behand(Roepnaam,nothing)
rule oplossing_h
    if dummy
    then oplossing_h becomes true
    and $ lookup(naam,personalia,Naamlijst)
    and $ zoeknaam(Naamlijst,Roepnaam)
    and $ message(['Er',kan,geen,diagnose,gegeven,worden,voor,Roepnaam,' '])
    and $ geef_behand(Roepnaam,nothing)
```

Delimitation of the problem

```
/*****************************************************************************************

      abstractie/0

      Dit predicaat wordt aangeroepen in de action anamnese uit opstartfile en zoekt een feit
      met predicaatnaam geselecteerd in het werkgeheugen. Als deze aanwezig is, dan wordt
      de probleemgroep met daaraan gekoppeld de lijst problemen (frames) opgehaald en
      vervolgens krijgen de frames plus de parents het attribuut probleem ( of erfelijk of
      obsprobleem) met de waarde ja. Fail zorgt ervoor dat er daarna een nieuw feit gezocht
      wordt (faildriven loop). Indien er geen feit meer aanwezig is, dan wordt dit gemeld
      (clause 2).

*****************************************************************************************/

abstractie :-
    geselecteerd(Probleemgroup,Problemen),
    geef_frames_waarden(Probleemgroup,Problemen),
    retract(geselecteerd(Probleemgroup,Problemen)),
    fail.
abstractie.

/*****************************************************************************************

      geef_frames_waarden(+Probleemgroup,+Problemen)

      Als de probleemgroep erflijst of obslijst heet, krijgen de concepten uit de lijst Problemen
      recursief attribuut erfelijk of obsprobleem met waarde ja. Van andere probleemgroepen
      krijgen de parent-concepten van concepten uit de lijst Problemen met
      geef_parents_waarden het attribuut probleem met waarde ja.

*****************************************************************************************/

geef_frames_waarden(Probleemgroup,[Item | Rest_Problemen]) :-
    Probleemgroup = erflijst,
    new_slot(erfelijk,Item,ja),
    geef_frames_waarden(Probleemgroup,Rest_Problemen).

geef_frames_waarden(Probleemgroup,[Item | Rest_Problemen]) :-
    Probleemgroup = obslijst,
     new_slot(obsprobleem,Item,ja),
    geef_frames_waarden(Probleemgroup,Rest_Problemen).
```

```
geef_frames_waarden(Probleemgroup,[Item | Rest_Problemen]) -
    Probleemgroup \= erflijst,
    Probleemgroup \= obslijst,
    geef_parents_waarden(Item),
    geef_frames_waarden(Probleemgroup,Rest_Problemen)

geef_frames_waarden(Probleemgroup,[])

/*****************************************************************************

      geef_parents_waarden(+Item)

      In een faildriven loop krijgen alle parent-concepten, als ze nog geen attribuut probleem
      met de waarde ja hebben, dit attribuut met deze waarde

*****************************************************************************/

geef_parents_waarden(Item) -
    ancestor(Item,Vader),
    not(isa_slot(probleem,Vader,ja)),
    new_slot(probleem,Vader,ja),fail
geef_parents_waarden(_)
```

```
/*****************************************************************************************

      De relation conclusie wordt gebruikt om na te gaan  welke domeinregels van toepassing
      zijn op de casus  Voor de actieve concepten wordt geconstateerd of ze voldaan hebben
      aan de regels voor dyslexie

*****************************************************************************************/

relation conclusie Conclusie voldoet
  if $ isa_default(conclusie,Concept,Conclusie)
  and $ is_voldaan(Concept)

relation conclusie Conclusie voldoet
  if $ isa _default(conclusie,Concept,Conclusies)
  and $ lst(Conclusies)
  and $ on(Conclusie,Conclusies)
  and $ is_voldaan(Concept)

/*****************************************************************************************

      is_voldaan/1

      Dit predicaat gaat  na of een concept is geactiveerd en gelabeld als problematisch in de
      anamnese, in het onderzoek of in observatie  Een prioritering is aangegeven t a v  de
      waarde van de gegevens  onderzoeksgegevens worden het hoogst gewaardeerd, dan de
      observatiegegevens en dan de anamnesegegevens

*****************************************************************************************/

is_voldaan(Concept)  -
   (isa_default(fase,Concept,anamnese),
    (isa_default(fase,Concept,Fasen),lst(Fasen),length(Fasen,2),
   on(anamnese,Fasen),on(verwijzing,Fasen))),
   isa_slot(probleem,Concept,ja)

is_voldaan(Concept)  -
    (isa_default(fase,Concept,observatie),
    (isa_default(fase,Concept,Fasen),lst(Fasen),length(Fasen,2),
    on(observatie,Fasen),on(verwijzing,Fasen))),
    isa_default(observatie,Concept,Observaties),
   (lst(Observaties) ->
      on(Observatie,Observaties),isa_slot(obsprobleem,Observatie,ja),
            isa_slot(obsprobleem,Observaties,ja))
```

```
is_voldaan(Concept) -
   (isa_default(fase,Concept,onderzoek),
    (isa_default(fase,Concept,Fasen),lst(Fasen),length(Fasen,2),
   on(onderzoek,Fasen),on(verwijzing,Fasen))),
  isa_default(onderzoek,Concept,Onderzoeken),
  (lst(Onderzoeken) ->
    (on(Onderzoek,Onderzoeken),onderzoek_voldoet(Onderzoek)),
    onderzoek_voldoet(Onderzoeken))

is_voldaan(Concept) -
   isa_default(fase,Concept,Fasen),lst(Fasen),
  on(anamnese,Fasen),on(observatie,Fasen),
  isa_slot(probleem,Concept,ja),
   isa_default(observatie,Concept,Observaties),
  (lst(Observaties) ->
      on(Observatie,Observaties),isa_slot(obsprobleem,Observatie,ja),
            isa_slot(obsprobleem,Observaties,ja))

is_voldaan(Concept) -
    isa_default(fase,Concept,Fasen),lst(Fasen),length(Fasen,2),
  on(anamnese,Fasen),on(onderzoek,Fasen),
  isa_slot(probleem,Concept,ja),
  isa_default(onderzoek,Concept,Onderzoeken),
  (lst(Onderzoeken) ->
    (on(Onderzoek,Onderzoeken),onderzoek_voldoet(Onderzoek)),
    onderzoek_voldoet(Onderzoeken))

is_voldaan(Concept) -
    isa_default(fase,Concept,Fasen),lst(Fasen),length(Fasen,3),
  on(anamnese,Fasen),on(observatie,Fasen),on(onderzoek,Fasen),
  isa_slot(probleem,Concept,ja),
  isa_default(onderzoek,Concept,Onderzoeken),
  (lst(Onderzoeken) ->
    (on(Onderzoek,Onderzoeken),onderzoek_voldoet(Onderzoek)),
    onderzoek_voldoet(Onderzoeken))
```

Definition of an individualized treatment plan

```
/*****************************************************************************************

      zoek_behand/1

      Dit predicaat  gaat na of de problematische concepten een behandelingsattribuut
      hebben  Indien dit het geval is, wordt het behandelingsaspect op het scherm
      afgedrukt

*****************************************************************************************/

zoek_behand(Problemen)  -
   isa_default(behandeling,Concept,Behandelingen),
   one(is_voldaan_vb(Concept)),
   write(Concept),writenl(' -> '),
   (lst(Behandelingen) ->
     drukaf_beh(Behandelingen),
      writenl(Behandelingen)),
   fail
zoek_behand(Problemen)

/*****************************************************************************************

      is_voldaan_vb/1

      Dit predicaat gaat  na of een concept is geactiveerd en gelabeld als problematisch in de
      anamnese, in het onderzoek of in observatie

*****************************************************************************************/

is_voldaan_vb(Concept)  -
   (isa_default(fase,Concept,anamnese),
    (isa_default(fase,Concept,Fasen),lst(Fasen),length(Fasen,2),
   on(anamnese,Fasen),on(verwijzing,Fasen))),
   isa_slot(probleem,Concept,ja)

is_voldaan_vb(Concept)  -
   (isa_default(fase,Concept,observatie),
    (isa_default(fase,Concept,Fasen),lst(Fasen),length(Fasen,2),
   on(observatie,Fasen),
     (on(nader_onderzoek,Fasen),on(verwijzing,Fasen)))),
   isa_default(observatie,Concept,Observaties),
   (lst(Observaties) ->
      on(Observatie,Observaties),isa_slot(obsprobleem,Observatie,ja),
            isa_slot(obsprobleem,Observaties,ja))
```

```
is_voldaan_vb(Concept) :-
   (isa_default(fase,Concept,onderzoek);
    (isa_default(fase,Concept,Fasen),lst(Fasen),
   on(onderzoek,Fasen))),
   isa_default(onderzoek,Concept,Onderzoeken),
   (lst(Onderzoeken) ->
     (on(Onderzoek,Onderzoeken),onderzoek_voldoet_vb(Onderzoek));
     onderzoek_voldoet_vb(Onderzoeken)).

is_voldaan_vb(Concept) :-
    isa_default(fase,Concept,Fasen),lst(Fasen),
   on(anamnese,Fasen),on(observatie,Fasen),
    isa_default(observatie,Concept,Observaties),
   (lst(Observaties) ->
       on(Observatie,Observaties),isa_slot(obsprobleem,Observatie,ja);
              isa_slot(obsprobleem,Observaties,ja)).
```

Problematic function areas

Physical functioning
Motor functioning
Spatial orientation
Laterality
Temporal sequence
Visual perception
Language
Scholastic functioning
Cognitive functioning
Personal functioning
Social functioning
Speech functioning

Assessment instruments[a]

Bannatyne Visuo-Spatial Memory Test
Coloured Progressive Matrices
Harris-test of lateral dominance
Konzentrations Verlauf test
Memory for Designs test
WISC-R
Taaltests voor Kinderen[b]
Een Minuut test[c]
Cito begrijpend lezen 3-4-5[d]

Diagnosis

Dyslexia
Nondyslexia (for example general learning disability or minimal brain dysfunction)

Treatment plan

General orthodidactic therapy
Auditory therapy
Reading therapy
Spelling therapy
Emotional and motivational therapy
Writing therapy
Language therapy
Visuo-motor therapy
Memory therapy
Visual therapy
Foreign language therapy
Speech therapy
Mathematics therapy
Physical therapy

[a] Some examples of 130 instruments
[b] Dutch language tests for children
[c] Dutch test for technical reading
[d] Dutch test for comprehension

Curriculum vitae

Anita Maria Blonk was born on the 9th of October 1962 in Rotterdam. From 1975 to 1982 she attended the Albert Einstein grammar school in Hoogvliet. In 1982 she started her academic profession at the University of Nijmegen. In 1988 she graduated both in the Interdisciplinary Program in Education, specialisation learning processes and in Educational Science, specialisation remedial education of learning problems.

In her first position (1988-1994) she participated as junior researcher in the research of the Diagnostic Unit at the Nijmegen Institute for Cognition and Information (NICI). She worked at the department of Remedial Education. The result of the project is described in this thesis.

Since 1994 she works as a lecturer at the department of Remedial Education at the University of Nijmegen especially in the field of learning problems of children. She is interested in formalising diagnostic and treatment procedures and the occurrence of behaviour problems in children with learning problems.

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